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OVERVIEW ON HORTICULTURE

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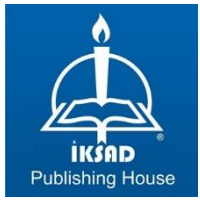

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PREFACE

Other plants aside, the place of Horticulture in our lives is completely different. This branch of science, which includes fruits, vegetables, vineyards and ornamental plants, is indispensable in our lives without losing its value from past to present. The value of plant species that meet both our nutritional and aesthetic requirements has been appreciated even more in the last few years. The fact that we were limited in every way during the pandemic process due to the Covid-19 epidemic reminded us how important health is. We overcame this difficult process by creating new behaviors on nutrition and psychology. We have created awareness about the production, consumption and sustainability of plants that we use as food (fruits, vegetables and vineyards) and that we use in recreation areas (ornamental plants). In short, we understood the necessity of preserving the place of Horticulture in our lives.

In this book, there are academic studies and opinions made with plants belonging to all subgroups of horticultural plants.

I would like to sincerely thank all our authors for sharing their valuable work and experience with the cultivation of some fruits, vegetables and vineyard plants and ornamental plants that we use for psychological and spiritual relaxation during the pandemic process, the problems encountered in cultivation (fighting plant pests, diseases and weeds; stress factors), biochemical ingredients, consumption as food. First of all, I say **'HEALTH'**, I wish you healthy days.

Sincerely Yours

Arzu ÇIĞ

CHAPTER I

SOME IMPORTANT INSECT SPECIES AND THEIR CONTROL METHODS ON APPLE TREES IN TURKEY

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INTRODUCTION

Turkey has an ecology where many fruit species can be grown due to the advantages offered by the climate zone it is in. Apple, which is one of the temperate climate fruits, is grown in almost every province. Turkey, which is one of the most important apple producers in the world with its genetic resources, has a wide trade area. Although Turkey ranks first in world production of an important pome fruit species such as apples; cannot compete in the international market due to inadequacies in efficiency, quality and marketing infrastructure (URL-1).

Intensive and unconscious pesticide use in apple production is a common problem. The annual average number of spraying is 15 times, and very successful results are obtained with excessive pesticides. Biological control based integrated control studies have reduced the annual number of sprayings from 15 to 8 against the main pest of Codling moth. It has been reported that efforts should be made to popularize all methods, including biological control, which are alternative methods of chemical control in apple production (URL-2).

Today, the protection of human health, the environment and biological diversity has come to the fore. For this reason, it has become a necessity to carry out agricultural struggle, taking into account the agro-ecosystem and sustainable agricultural production. It has been reported that this can only be achieved by prioritizing alternative methods to chemical control, especially biological control, and if necessary, by using them together and in harmony (Anonymous, 2011).

Nearly 500 of the over 6500 apple varieties available in the world are in Turkey. Apple is an important type of fruit in terms of the abundance of the product taken from the decare, its wide variety, its resistance to cold climates and its use in industry in many different ways. Turkey is one of the most important countries in world apple production. Although its place in the ranking changes from year to year, it has been reported that it is among the top 5 countries in the world in terms of apple production area and amount (URL-3).

Considering the production amount of important products among fruits, it was reported that apple increased by 18.8% compared to the previous year (URL-4).

1. INSECT SPECIES

1.1. *Cydia pomonella* (Linnaeus, 1758) (Codling Moth) (Lepidoptera: Tortricidae) (Figure 1)

a **b**

Figure 1: *Cydia pomonella* a) Adult b) Damage in Apple Fruit (URL-5, URL-6)

It is the main pest of apples. It spends the winter in the larval stage under the scorched bark of the trees, in the cocoon they weave in cracks and crevices. In April, it becomes pupa in cocoon. After mating, females lay their eggs one by one on apple leaves. The caterpillars that come out of

the egg go into the fruit by gnawing the shell of the fruit and reach the seed house by opening galleries and feeding. The caterpillar, which has completed its development, leaves the fruit and weaves a cocoon between the leaves falling to the ground on the tree bark, especially in the cracks and crevices on the trunk, and becomes a pupa. The female butterflies of the second and third generations lay their eggs mostly on fruits. The development threshold of the pest is 10^{o}C and its thermal constant is 625 day degrees. It has 2-3 generations per year, depending on the regions (Anonymous, 2017).

Control Methods:

a) Cultural measures: The fruits that fall under the apple trees should be collected and removed. In addition, the loose bark of the trees should be cleaned to prevent the larvae from becoming pupae (Anonymous, 2015).

b) Biotechnical control: In this method, which is done for the purpose of surprise, the pheromone of the females is also carried out with pheromone sticks containing wire.

When the first adults are seen in the tracking traps, these sticks are hung homogeneously at a height of 1.5-2 m from the ground, 100 pieces/da, one on each of the shadow parts and four sides of each tree. Since their effect period is 120-140 days, they only need to be tied to trees once during a season (Anonymous, 2013) (Figure 2).

Figure 2: Sticks with Pheromones Used in Biotechnical Control for Baffling (URL-7)

c) Biological control: *Steinernema carpocapsae* is able to achieve a high level of success in the control of the internal weevil larvae overwintering in apple orchards. *S. carpocapsae* and *S. feltiae* are mostly used in the control of the pest (Yağci et al., 2021).

d) Mechanical control: In addition, before the larvae come to the tree bark to hide in the autumn, they can be caught by preparing suitable environments for them to spend the winter.

a **b**

Figure 3: a) Corrugated Cardboard Used for Catching Codling Moth Larvae b) Larvae in Corrugated Cardboard (URL-8, URL-9)

For this reason, if materials such as sacks and corrugated cardboard are wrapped around the trunks of trees, the larvae of the pest settle in these more sheltered places instead of the bark to spend the winter (Figure 3). These substances are removed after the weather has completely cooled down and the larvae inside are killed. The same application in the summer II. generation can also be made for mature larvae.

e) Chemical control: With pesticides effective against eggs, pesticides can also be applied against the eggs before the caterpillars that hatch from the eggs enter the fruit.

1.2. *Drosophila suzukii* (Matsumura, 1931) (Spotted Wing Drosophila) (Diptera: Drosophilidae) (Figure 4)

Figure 4: *Drosophila suzukii* Adults (Male on the Left, Female on the Right) and Its Damage on the Cherry (URL-10, URL-11)

This species, which has been seen in our country since 2014, has started to cause damage primarily to cherries. Later, it started to be damaged in apples as well as various fruits (Orhan et al., 2016).

It overwinter as an adult in sheltered places, but under suitable conditions it can be active all year round. It starts to be active when the air temperature reaches 10°C from the spring. In the spring, the adults mate and lay eggs on the ripe fruit. Females can lay 300-600 eggs. Just as a female lays more than one egg on the same fruit, other females lay eggs on the same fruit. Adults can fly several kilometers. High humidity and mild climatic conditions create suitable environments for its development. The larvae that emerge from the eggs begin to feed inside the fruit. It goes through three larval stages. It then pupae inside the fruit or in the soil. Under favorable conditions, the life cycle of this pest lasts for 10 days. It can produce 7-15 generations per year (Cini et al., 2012; Arıdıcı-Kara & Ulusoy, 2020).

Unlike other *Drosophila* spp., this species feeds on ripe, healthy and decaying fruit species on the tree. It causes the damage by feeding the larvae inside the fruit. Since more than one larva can be found in a fruit, the signs of softening and decay increase rapidly. Later, fungal and bacterial infections occur (Lewis et al., 2019).

Control Methods:

Presence of larvae in cherry fruit is done using saline solution. For this; 30 healthy fruits, randomly collected, are placed in a plastic bag. Put 4 glasses of water and 1/4 measure of salt in it. Wait 10-15 minutes and watch the larvae start to swim in the water.

-Cultural measures: Harvesting should be started immediately when the fruits are ripe and no fruit should be left on the tree after harvest.

Harvesting should be done without delay in gardens known to be contaminated. Fruits spilled on the ground in the gardens determined to be contaminated should be collected and buried in a suitable area at a depth of at least 30 cm. Irrigation in gardens should be done with a drip irrigation system. In particular, excessive irrigation of the gardens near the harvest should be avoided.

-Biotechnical control: In gardens known to be infested with pests, vinegar traps are hung from the beginning of April, surrounding the garden and neighboring gardens, which are known to be contaminated, before the adults lay eggs. Traps are hung along the edges of the garden in 1 row and at a maximum spacing of 5 m. On the other trees in the same garden, 4-5 vinegar traps are hung per tree, and mass trapping method is applied in the control of the pest. This process continues throughout the year.

-Biological control: It is effective in reducing the population of predator species such as *Anthocoris nemoralis* and *Orius levigatus* (Hemiptera: Anthocoridae) in biological control of the pest.

1.3. *Anthonomus pomorum* (Linnaeus, 1758) (Apple Blossom Weevil) (Coleoptera: Curculionidae) (Figure 5)

The damage is significant, as the larvae feed and develop inside the flower buds. It spends the winter under the scorched bark on the trunk and branches of trees or between crevices and cracks. When the average daily temperature is 7-8 °C, the adults leave the winter quarters.

a **b**

Figure 5: *Anthonomus pomorum* a) Adult b) Larva feeds on the Bud (URL-12, URL-13)

From mid-February to the end of March, it is fed with the buds, sprouts and shoots of the trees. They mate and lay their eggs in flower buds that are still pollinating. Larvae develop in 2-4 weeks and pupate in the same flower house. Generally, the pupal period ends in May and the emerging adults are fed with fresh leaves and shoots for a short time and withdraw to their winter places towards the middle of summer. It has one generation per year.

Since the larvae of the apple eye worm feed and develop within the flower buds, the damaged flower cannot open and set fruit. Flowers of this type turn brown and dry. Adults feed on fresh leaves, sprouts and shoots besides flowers (Anonymous, 2008a).

Control Methods:

-Mechanical control: From the bursting of the eyes, until the flower buds appear, the adults that fall by laying sheets under the trees and shaking the branches, and the damaged flowers before the emergence

of the adult should be collected and buried in the soil. In the branch controls to be made in winter or during pruning, the branches with damaged eyes should be cut and removed (Anonymous, 2011).

-Chemical control: In the gardens known to be infested with *A. pomorum*, spraying is done as soon as the adults start to work as of March and the above threshold is reached. The most suitable time is phenologically the period of the mouse ear. Spraying should be finished when flower buds begin to appear. If spraying cannot be done at this time for any reason, damaged flower buds are placed in a cage after the flower petals are completely shed in the first week of May. Late spring spraying is done one week after the onset of adult emergence is detected by daily controls (Anonymous, 2017).

1.4. *Tropinota hirta* (Poda, 1761) (Apple Blossom Beetle) (Coleoptera: Cetoniidae) (Figure 6)

a **b** **c** **d**

Figure 6: *Tropinota hirta* a) Adult b) Larva c) Pupa (Anonymous, 1962) d) Damage in flowers (Orijinal by Yaşar)

Apple and pear are his favorite hosts. This pest spends the winter in the soil in the larval and adult stages. The adults, which emerge in the

spring when fruit trees and other plants bloom, feed on flowers. Its larvae feed on the roots of grasses. It becomes pupa in the soil. Adults emerging from these pupae spend the winter in the soil. Adults are very active during the sunny hours of the day. At the end of spring, its population reaches its highest level. In some areas, they can be seen flying until mid-July. Adult insects damage the female and male organs of the flowers of fruit trees and other plants, by eating young leaves, even buds and fruits (Yaşar, 2018).

Control Methods:

-Biotechnical control: It has been reported that blue colored funnels containing attractants, which are used in gardens that are not sprayed at the time of flowering, can be used as an effective method in the fight against this pest (Sağdaş & Yaşar, 2013).

It has been reported that rain water is evacuated by making holes in the top 1/3 of the 1 L plastic bottles filled with 1/3 water under the distant blue funnels hanging from the branches at a height of 1.5 m from the ground, so small that insects cannot escape (Figure 7) (Yaşar & Dahham, 2018).

-Cultural measures: It can be ensured that the pest population decreases significantly by killing the larvae and adults in the soil by plowing with a plow in our own garden and other gardens in the nearby areas (Yaşar, 2018).

Figure 7: Light Blue Funnel Trap with Attractant Used Against *Tropinota hirta* (Yaşar & Dahham, 2018)

1.5. *Lepidosaphes ulmi* (Linnaeus, 1758) (Mussel Scale) (Hemiptera: Diaspididae) (Figure 8)

a **b**

Figure 8: *Lepidosaphes ulmi* a) Females b) Damage in Apple Fruit (URL-14)

It is a polyphagous species. It also damages soft and stone fruit trees. It spends the winter in the form of eggs under the shell of the females. At the end of April-early May, the first active larvae (crawlers) of the first generation emerge and begin to feed. They become adults by changing

two shirts. The active larvae of the second generation emerge from the eggs towards the middle of July, they are fed until the end of summer, the females that are formed begin to lay eggs under their own shell in mid-September. It has two generations per year.

Control Methods:

-Cultural measures: In winter, infested branches should be pruned and removed from the garden.

-Biological control: *Aphytis mytilaspidis* (Hymenoptera: Aphelinidae) is an effective external parasitoid of the pest. In addition, *Hemisarcoptes malus* (Acarina: Hemisarcoptidae), *Cheletogenes ornatus* (Acarina: Cheyletidae), *Temnostethus dacicus*, *T.longirostris*, *T.reduvinus* (Hemiptera: Anthocoridae), *Cybocephalus fodori* (Coleoptera: Cybocephalidae) are important and effective predators.

If heavy spraying is avoided, the natural enemies mentioned above can usually keep this pest under pressure. Summer spraying should not be done unless it is necessary against this pest.

-Chemical control: Chemical control against Mussel scales is carried out in the form of winter and summer sprays. Winter spraying should be done 2-3 weeks before the buds appear on pome fruit trees. Spraying can be done during the period when most of the eggs are hatched.

1.6. *Synanthedon myopaeformis* (Borkhausen, 1789) (Red-belted Clearwing) (Lepidoptera: Sesiidae) (Figure 9)

It spends the winter as larvae in the galleries inside the bark of the trunk and thick branches of apple trees. In the spring, the larvae become active and begin to feed by opening galleries inside the shells. The mature caterpillars pupate in the gallery.

a **b**

Figure 9: *Synanthedon myopaeformis* a) Adult b) Larva and Its Damage to the Tree Trunk (URL-15)

The first butterflies appear in early June. Females lay their eggs in cracks and crevices on the trunk and branches. The caterpillars hatching from the eggs that hatch after 10-15 days feed by opening galleries in the bark of the trunk and thick branches. It has one generation per year.

Control Methods:

-Cultural measures: The larvae on the tree bark should be cleaned with a knife during the winter and the wounds should be closed with putty.

-Biotechnical control: Molasses food traps attract adults and are caught in mass and the pest population can be reduced. For this, a fattening trap

with molasses is hung on 5 trees in a garden of 100 trees. For 1 L of mix:

1 part molasses + 5 parts water + 2-3 g baker's yeast or 2/3 wine + 1/3 water for 1 L + 20-30 g sugar + 2 tablespoons vinegar is mixed and hanged on the trees during the adult flight period.

-Chemical control: Chemical control of Red-belted clearwing is very difficult. In March or April, the trunk and thick branches of at least 20 trees are checked in a garden, and if more than five live larvae are detected in a tree, spraying is required.

1.7. *Hoplocampa testudinea* (Klug, 1816) (Apple sawfly) (Hymenoptera: Tenthredinidae) (Figure 10)

a **b**

Figure 10: *Hoplocampa testudinea* a) Adult b) Damages in Apple Fruits (URL-16, URL-17, URL-18)

It is especially harmful to stone fruit trees. It spends the winter in the soil as a larva in the cocoon. After the adults that emerge in the spring are mated, the females lay their eggs at the bottom of the unopened or half-opened flowers, on the outer surface of the leaves, under the epidermis through the slit they open with their ovipositors. The larvae first feed by opening superficial galleries in the fruit shell. It then

proceeds to the core house. Most of the damaged fruits fall when they are younger. The less active adults hide in the flowers that are about to open and feed on pollen. Its harms are mixed with “Codling moth”. It has one generation per year (Anonymous, 2017).

Control Methods:

-Mechanical control: Fruits falling to the ground should be collected, buried deeply and the garden soil should be plowed deeply in winter.

1.8. *Eriosoma lanigerum* (Hausmann, 1802) (Woolly Apple Aphid) (Hemiptera: Aphididae) (Figure 11)

a **b**

Figure 11: *Eriosoma lanigerum* a) Female b) Galls Formed on Apple Branches (URL-19, URL-20)

It is a harmful species in apples. It spends the winter as nymphs in the root collar of apple trees and among the wounds or tumors on the branches. It becomes active as of March and forms colonies on branches and shoots. As a result of the sting and sucking of the insect on the branches and shoots, galls form on the plant. It reproduces completely parthenogenetically. It has 10-12 generations per year (Anonymous, 2011).

Control Methods:

-Cultural measures: It is known to cause little damage to apple varieties such as Amasya apple, Jonathan, Golden Delicious. These varieties should be included when establishing the garden.

-Mechanical control: Gall, tumors and wounds should be cut and burned.

-Biological control: The most effective natural enemy is the internal parasitoid called *Aphelinus mali* (Hymenoptera: Aphelenidae). This parasitoid, which is also found in our country, is quite effective. Its population should be protected by avoiding unnecessary spraying. Ants should be destroyed as they inhibit parasitoid activity. For this, the soil surface near the root collar of the trees is sprayed with powder pesticides (Yaşar, 2018).

1.9. Aphids (Hemiptera: Apdididae) (Figure 12)

a **b**

Figure 12: a) Damage of *Dysaphis devecta* on apple leaves b) *Dysaphis plantaginea* Galls on Leaves (URL-21, URL-22)

The most important aphids on apple trees are *Aphis pomi* De Geer, 1773 (Green apple aphid), *Dysaphis devecta* (Walker, 1849) (Rosy leaf-curling aphid) and *Dysaphis plantaginea* (Passerini, 1860) (Rosy apple aphid).

1.10. *Lymantria dispar* (Linnaeus, 1758) (Gypsy Moth) (Lepidoptera: Erebidae) (Figure 13)

a **b**

Figure 13: *Lymantria dispar* a) Female b) Male (URL-23)

It is a harmful species on apple, pear and hazelnut trees. It spends the winter in the egg stage, which is left in packages on trees. One package contains 400-500 eggs. Caterpillars hatching from eggs in spring feed on the leaves of fruit trees. The mature caterpillars descend to the soil and become pupae in the soil. Butterflies emerge from the pupae in late August and the females mate and lay their eggs. It has one generation per year (Anonymous, 2008b).

Control Method:

-Biological control: The most effective natural enemy is the predator named *Calosoma sycophanta* (Coleoptera: Carabidae).

1.11. *Phyllonorycter gerasimowi* (Hering, 1930) (Leaf-mining moths) (Lepidoptera: Gracillariidae) (Figure 14)

It is harmful to apple trees. It spends the winter in the pupa stage in the galleries of fallen apple leaves. Adults emerge in April. Mating females lay their eggs one by one on the underside of the apple leaf. Larvae emerging from the egg enter the parenchyma tissue of the leaf and open galleries. The galleries are oval shaped when viewed from the upper surface of the leaf, and have a greenish and whitish mosaic appearance as dots. The caterpillars that complete their development become pupae in the gallery. It has 3-4 generations per year (Yaşar, 2018).

a **b**

Figure 14: *Phyllonorycter gerasimovi* a) Adult b) Galleries in Apple Leaves (URL-24)

Control Method:

-Cultural measures: Leaf gallery moths spend the winter under the trees, among the fallen leaves, in the soil, under the bark of the trees, so the collection and destruction of the dried leaves in the gardens, plowing the soil, peeling the bark will reduce the pest population.

Chemical control should not be made against these pests unless it is necessary.

1.12. *Stigmella malella* (Stainton, 1854) (Apple Pygmy) (Lepidoptera: Nepticulidae) (Figure 15)

It is harmful to apple trees. It spends the winter as a pupa in a cocoon it knits in the depths of the soil between 0.5-9 cm. It matures in the spring. Females lay their eggs on the underside of apple leaves.

a **b**

Figure 15: *Stigmella malella* a) Adult b) Galleries of İts Larva in Apple Leaf (URL-25, URL-26)

The caterpillars that emerge from the egg first open a long, thin gallery in the parenchyma tissue of the leaf. As the development of the caterpillars progresses, the width of the galleries increases and becomes curved. It has four generations per year (Anonymous, 2017).

Control Method:

-Mechanical control: In apple orchards, the soil should be processed deeply. Thus, the harmful pupae in the soil are killed.

Other than the insect species described above, less harmful species are given below:

Anthonomus amygdali, *Scolytus rugulosus* (Coleoptera: Curculionidae); *Anoplophora chinensis*, *Cerambyx cerdo*, *Cerambyx dux* (Col.: Cerambycidae); *Carpophilus* spp. (Col.: Nitidulidae); *Ceratitis capitata* (Diptera: Tephritidae); *Coleophora prunifoliae* (Dipt.: Coleophoridae); *Cicadella viridis* (Hemiptera: Cicadellidae); *Monosteira unicostata* (Hem.: Tingidae); *Epidiaspis leperii*, *Parlatoria oleae* (Hem.: Diaspididae); *Rhopalosiphon insertum* (Hem.: Aphididae); *Comstockaspis perniciosa* (Hem.: Diaspididae); *Ceroplastes floridensis* (Hem.: Coccidae); *Ceresa bubalus* (Hem.: Membracidae); *Apodiphus amygdali* (Hem.: Pentatomidae); *Cacopsylla mali* (Hem.: Psyllidae); *Stephanitis pyri* (Hem.: Tingidae); *Caliroa cerasi* (Hymenoptera: Tenthredinidae); *Neurotoma flaviventris* (Hym.: Pamphiliidae); *Siphoninus phillyreae* (Hem.: Aleyrodidae); *Cossus cossus, Zeuzera pyrina* (Lepidoptera: Cossidae); *Euproctis chrysorrhoea* (Lep.: Erebidae); *Anarsia lineatella; Recurvaria nanella* (Lep.: Gelechiidae); *Operophtera brumata* (Lep.: Geometridae); *Malacosoma neustria* (Lep.: Lasiocampidae); *Leucoptera malifoliella* (Lep.: Lyonetiidae); *Aporia crataegi* (Lep.: Pieridae); *Apomyelois ceratoniae* (Lep.: Pyralidae); *Cryptoblabes gnidiella* (Lep.: Pyralidae); *Grapholita molesta* (Lep.: Tortricidae); *Hedya nubiferana* (Lep.: Tortricidae); *Pandemis cerasana* (Lep.: Tortricidae); *Spilonota ocellana* (Lep.: Tortricidae); *Yponomeuta malinellus* (Lep.: Yponomeutidae); *Yponomeuta padella* (Lep.: Yponomeutidae); *Frankliniella occidentalis* (Thysanoptera: Thripidae)*; Taeniothrips inconsequens* (Thys.: Thripidae) (Yaşar, 2018).

CONCLUSION

In this article, brief information is given about the biology and control of some of the important insect species that harm apples in Turkey. The point that should be emphasized is that other control methods should be tried before deciding on chemical control against these pests. Although some of these methods are very simple and cheap, they are not widely adopted by the manufacturers. However, taking into account the negative effects of pesticide applications, it is a fact that choosing methods that have no negative effects on the environment, people and other living things, such as newly applied biotechnical and biological control methods with very high success, will reduce the use of pesticide in plant production.

REFERENCES

Anonymous, (1962). Bayer Pflanzenschutz-Compendium II. Farbenfabriken Bayer Leverkusen.

Anonymous, (2008a). Soft and Hard Seed Fruit Pests. Ankara.

Anonymous, (2008b). Agricultural Control Technical Instruction, Volume, 4. Republic of Turkey Ministry of Agriculture and Forestry General Directorate of Agricultural Research and Policies, Department of Plant Health Research, Ankara.

Anonymous, (2011). Apple Integrated Control Technical Instruction. T.C. Republic of Turkey Ministry of Agriculture and Forestry General Directorate of Agricultural Research and Policies, Department of Plant Health Research, Ankara.

Anonymous, (2013). Biotechnical Struggle From Theory to Practice (Ed.: Birişik, N.). Agriculture and Forestry General Directorate, Ankara.

Anonymous, (2015). Cultural Struggle From Theory to Practice (Ed.: Birişik, N.). Agriculture and Forestry General Directorate, Ankara.

Anonymous, (2017). In Apple, Pear and Quince Integrated Control Technical Instruction. Republic of Turkey Ministry of Agriculture and Forestry General Directorate of Agricultural Research and Policies, Department of Plant Health Research, Ankara.

Arıdıcı-Kara, P. & Ulusoy, M.R. (2020). Distribution areas and hosts of *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae) in the Eastern Mediterranean Region. Cukurova University Journal of the Faculty of Engineering, 39(5): 125-137.

Cini, A., Ioriatti, C., & Anfora, G. (2012). A review of the invasion of *Drosophila suzukii* in Europe and a draft research agenda for integrated pest management. Bulletin of Insectology, 65(1): 149-160.

Lewis, M.T., Koivunen, E.E., Swett, C., & Hamby, K.A. (2019). Associations between *Drosophila suzukii* (Diptera: Drosophilidae) and fungi in raspberries. Environmental Entomology, 48(1): 68-79.

Orhan, A., Aslantaş, R., Önder, B.Ş., & Tozlu, G. (2016). First record of the invasive vinegar fly *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae) from eastern Turkey. Turkish Journal of Zoology, 40: 290-293.

Sağdaş, A. & Yaşar, B. (2013). The effect of various types of blue traps baited with an attractant on the adult captures of the apple blossom beetle (*Tropinota hirta* (Poda) (Coleoptera: Scarabaeidae) in sweet cherry orchards of Afyonkarahisar. Suleyman Demirel University, Journal of Natural and Applied Science, 17(3): 26-31.

Yağci, M., Özdem, A., Erdoğuş, F.D., & Ayan, E. (2021). Efficiency of entomopathogenic nematodes (Rhabditida: Heterorhabditidae and Steinernematidae) on the codling moth (*Cydia pomonella* L.) (Lepidoptera: Tortricidae) under controlled conditions. Egyptian Journal of Biological Pest Control, 31, 75.

Yaşar, B. (2018). The Pests of Fruit Orchards and Vineyards in Turkey. Olgun-Çelik Pub, Konya.

Yaşar, B. & Dahham, O.A.D. (2018). The impact of traps on different apple varieties on catching of the adults of *Tropinota hirta* Poda (Coleoptera: Cetoniidae). 6th ASM, International Congress of Agriculture and Environment, Antalya, 11-13 October.

URL-1:http://www.turktarim.gov.tr/Haber/368/en-cok-starking-ve-golden-uretiyoruz (Access date: 25.06.2021)

URL-10:https://en.wikipedia.org/wiki/Drosophila_suzukii#/media/File: DrosophilasuzukiiphotoMcEvey.jpg (Access date: 23.06.2021)

URL-11:http://entnemdept.ufl.edu/creatures/fruit/flies/drosophila_suzukii.htm (Access date: 15.03.2021)

URL-12:http://www.botanikkafa.com/goz-kurtlari-anthonomus-spp./ (Access date: 02.03.2021)

URL-13:http://baza.biomap.pl/en/taxon/species-anthonomus_pomorum/ photos_rc/tr/y) (Access date: 03.04.2021)

URL-14: http://agrodelo.com.ua/sad/vrediteli-jablon.html (Access date: 05.05.2021)

URL-15: http://www.lepiforum.de/lepiwiki.pl?Synanthedon_Myopaeformis (Access date: 08.06.2021)

URL-16:https://waldenheightsnursery.com/european-apple-sawfly (Access date: 17.05.2021)

URL-17: (http://www.biolib.cz/en/image/id3419/) (Access date: 05.04.2021)

URL-18:(https://www.rhs.org.uk/advice/profile?PID=644) (Access date: 05.06.2021)

URL-19:http://www.fond-ecran-image.com/galerie-membre/puceron-lanigere/puceron-lanigere-ou-laineux-2.jpg (Access date: 11.05.2021)

URL-2:https://www.zmo.org.tr/genel/bizden_detay.php?kod=32410&tipi=38 (Access date: 05.05.2021)

URL-20: http://eagri.tnau.ac.in/eagri50/ENTO331/lecture20/apple_001.html (Access date: 03.06.2021)

URL-21:http://influentialpoints.com/Gallery/Dysaphis_devecta_species_ group_rosy_leaf-curling_apple_aphids.htm (Access date: 16.04.2021)

URL-22:http://influentialpoints.com/Gallery/Dysaphis_plantaginea_ Rosy_apple_aphid.htm (Access date: 29.06.2021)

URL-23: http://butterfly-conservation.org/51-1376/gypsy-moth.html (Access date: 09.03.2021)

URL-24: http://www.ffs.sk/20-2015/07-tokar-et-al/ (Access date: 12.05.2021)

URL-25:https://ricosz.flog.pl/wpis/4800615/pasynek-jabloniowy-stigmella-malella#w (Access date: 23.02.2021)

URL-26:http://kentmicromoths.blogspot.com.tr/2012_07_01_archive.html (Access date: 11.04.2021)

URL-3: http://www.turktarim.gov.tr/ (Access date: 05.06.2021).

URL-4:https://data.tuik.gov.tr/Bulten/Index?p=Bitkisel-Uretim-Istatistikleri-2020-33737 (Access date: 07.06.2021)

URL-5:http://idtools.org/id/leps/tortai/Cydia_pomonella.htm (Access date: 09.06.2021)

URL-6: https://content.ces.ncsu.edu/codling-moth (Access date: 05.03.2021)

URL-7:https://www.biocontrol.ch/de_bc/isomate-dispensperm (Access date: 03.06.2021)

URL-8:htthp://es.paperblog.com/mosca-de-la-fruta-su-gran-enemigo-671536/) (Access date: 12.05.2021)

URL-9:https://www.karamandan.com/Tarim-Elma_Kurduna_karsi_mucadele-h38825.html (Access date: 02.06.2021) (Access date: 16.04.2021)

CHAPTER II

OVERVIEW OF CHARACTERISTICS OF THE *Citrus* GENUS

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INTRODUCTION

The genus *Citrus* L., which belongs to the Rutaceae family, consists of different forms such as trees, shrubs, and herbs in the world (Upadhyay et al, 2010; Javed et al, 2013; Sicari et al., 2018, Wang et al., 2019a). *Citrus* is the most cultivated and traded fruit variety in the world as a garden plant (Lv et al., 2015; Adenaike & Abakpa, 2021; Wu et al., 2021) and one of the most important commercial fruit crops grown on all continents of the world. It is grown especially in tropical and subtropical regions and some countries of the Mediterranean Basin such as Greece, Italy, Spain, Tunisia and Turkey, as well as important citrus producers, in regions with Mediterranean climate such as Australia, California, Florida, and South Africa (Zou et al., 2016; Amutha et al., 2017; Vitale et al., 2021). Although most researchers say that the homeland of citrus is South East Asia, it is claimed that the origin of citrus fruits is not known with certainty (Okwu, 2008). In ancient times, citrus was used not only as food but also in folk medicine against many complaints such as bronchitis, tuberculosis, cough, cold, menstrual irregularity, hypertension, anxiety, depression, and stress (Pallavi et al., 2016).

Citrus fruits are grown in an ever-expanding area around the world; The most well-known and commercially preferred *Citrus* species are mandarin (*Citrus reticulata* Blanco), orange (*Citrus sinensis* (L.) Osbeck), pomelo (*Citrus maxima* (Burm.) Merr.), lemon (*Citrus limon* (L.) Osbeck), lime (*Citrus aurantiifolia* (Christm.) Swingle) and citron (*Citrus medica* L.), grapefruit (*Citrus paradisi* Macfad.) (Wang et al.,

2019a). Citrus fruits are among the most accepted and preferred fruits in the world not only with their taste but also with their taste and general health benefits (Amutha et al., 2017).

C. limon is a small evergreen plant with an acidic juice, with thorny branches, white flowers with purple edges, polyembryonic, usually grown in subtropical regions (Chekani et al., 2021; Ehiobu et al., 2021). *C. limon* contains vitamin C, potassium, flavonoids and essential oils (Garcia Beltran et al., 2017). Thanks to many phytochemical components such as alkaloid, flavonoid, saponin, steroid, terpenoid, cardiac glycosides found in *C. limon* peel and leaf, it has antimicrobial, antifungal, antiviral, anticancer, antioxidant effects (Chekani et al., 2021; Ehiobu et al., 2021).

Citrus limetta Risso and *Citrus grandis* (L.) Osbeck are widely grown in Central and Southeast Asia, as they are a source of vitamin C, folic acid, potassium and pectin (Gupta et al., 2021).

Citrus aurantium L., known as sour orange, bitter orange or Seville orange, which has commercial value, is used as a medicinal and nutritional supplement, although it is not used as an edible fruit due to its sour and bitter taste. The sour taste of *C. aurantium* is mainly due to the presence of naringin, neohesperidin. It is used as an alternative to lemon juice in vegetable salads and appetizers in Turkey. Its use is common in the western and southern regions of Turkey (Karabıyıklı et al., 2014). Its by-product bark is mostly used as animal feed, its fruits are generally used as jam and flavoring due to its anticancer,

antioxidant, antidiabetic, cardioprotective, antiobesity, antioxidant effects (Hosseini et al., 2016; Ersus & Cam, 2007; Wang, et al., 2019b). *C. aurantium* has been used in traditional Chinese medicine to treat depression-like symptoms (Suntar et al., 2018).

Although Calamansi (*Citrus* × *microcarpa* Bunge) (In Malaysia it is known as limau kasturi) does not have a sharp taste like lemon or lime, it is used in the preparation of soft drinks by mixing sugar, especially in Southeast Asia, and has a very high commercial value (Hoyle & Santos, 2010).

The blood orange (*C. sinensis*) is the orange variety most commonly grown in Italy (Moro, Tarocco, and Sanguinello). These varieties have more anthocyanins, vitamin C, flavanones, hydroxycinnamic acid than regular oranges (Rapisarda et al., 2001). Major anthocyanins in blood oranges; cyanidin 3-glucoside and cyanidin 3-(600 malonyl)-glucoside. The fact that it has a higher antioxidant ratio than the normal orange is associated with the level of anthocyanins (Rapisarda et al., 2009). Besides having strong antioxidant and chemoprotective properties, anthocyanins play a role in defense against many diseases such as capillary fragility, diabetic renopathy, and human platelet aggregation (Mazza & Miniati, 1993; Wang et al., 1997; Natella et al., 1999; Kähkönen & Heinonen, 2003; Rapisarda et al., 2009).

Grapefruit (*C. paradisi*) is one of the most consumed *Citrus* species. Although the most common type is the *C. paradisi* Marsh with its bitter taste, it was desired to reduce the bitterness by crossing it with orange,

but in these crosses, a decrease in color opening and ascorbic acid ratio and an increase in fructose ratio is observed (Sicari et al., 2018). Thanks to the secondary metabolites with antioxidant properties in grapefruit, it has been found that it reduces atherosclerotic plaque formation (Cerda et al., 1994), prevents breast cancer cell proliferation and tumor formation in breast cells (Sicari et al., 2018). Thanks to the high amount of naringenin, naringin and flavonoids in its content, positive results have been obtained in many studies such as anticancer activities and inhibition of platelet aggregation (Sicari et al., 2018).

Clementine (*Citrus clementina* Hort. ex Tan.) is a citrus variety grown in the southern regions of Italy. It is a rich source of bioactive substances containing vitamin C and phenolic compounds (Strano et al., 2021).

Essential oils are hydrophobic aromatic oils obtained from many parts of the plant (such as flowers, buds, bark, fruit) (Olantunya & Akintayo, 2017). The *Citrus* genus has essential oils that give it its unique scent. Glands give the fruit its characteristic odor and the interior is rich in soluble sugars, ascorbic acid, pectin, fibers, different organic acids, potassium salt, which gives the fruit its unique citrine flavor (Okwu, 2008). Citrus essential oils are a by-product of the fruit. Essential oils have antimicrobial, antifungal, anticancer, antiviral, antioxidant properties and are used in gastronomy to flavor beverages and foods, and in the cosmetics industry for soap and perfumes (Okwu, 2008; Upadhyay et al., 2010; Rafiq et al., 2018). Essential oils from citrus are important flavoring ingredients in foods and beverages. The

consumption of essential oil in the last ten years is estimated to be 56,200 tons per year (Schmidt, 2010).

In a study, 14 *Citrus* species were studied, and it was found that the essential oils (EO) obtained varied between 0.95% and 2.8%. More than two hundred compounds have been identified, accounting for 92.84-99.67% of the total EOs recorded. It has been found to consist of terpenes (most abundant), alcohols, aldehydes, esters, ketones, acids, and minor amounts of other substances. All samples contained D-limonene (39.77-80.13%), α-pinene (1.83-13.97%), myrcene (0.8-7.63%), okimene (0.01-4.52%) and linalool (0.13-8.52%) as major compounds (Guo et al., 2018).

In a study, *C. sinensis* and *C. maxima* essential oils were examined and as a result of GC analysis, *C. sinensis* and *C. maxima* major compounds were found to be DL-Limonene with 90.66% and 31.83%, respectively (Singh et al., 2010).

1. CITRUS PRODUCTION AND CONSUMPTION WITH DATA

Citrus production in the world reached 91,879 thousand tons (orange: 46,062 thousand tons, tangerine: 31,568 thousand tons, lemon: 7,550 thousand tons, grapefruit: 6,699 thousand tons) in 2019. In consumption, a total of 70,177 thousand tons were consumed in the world in 2019 (orange: 28,324 thousand tons, tangerine: 30,117 thousand tons, lemon: 5,664 thousand tons, grapefruit: 6,072 thousand tons). In 2019, 10 million tons of citrus fruits were exported around the world. Orange had the highest share in exports with 45%, followed by

mandarin with 27%, lemon with 19% and grapefruit with 9%. In the world orange export, which was approximately 4.6 million tons in 2019, Egypt takes first place with a share of 33%. Egypt is followed by South Africa with 28% export share and the USA with 11% share. In the same year, the leading countries in tangerine exports were Turkey 31%, China 26% and Morocco 14%, respectively. Mexico has 39%, South Africa 21% and Turkey 19% in lemon exports. In the grapefruit export, South Africa took its place with a share of 30%, China with a share of 28% and Turkey with a share of 21%.

Although Turkey produced approximately 4.3 million tons of citrus fruit in 2019, almost all of the production is provided from the Aegean and Mediterranean Regions.

In 2019, 1.5 million tons of citrus fruits were exported in Turkey. Tangerines had a share of 44%, lemon 31%, orange 16% and grapefruit 9% from this export. When we look at the leading countries in Turkey's citrus exports in 2019; It is seen that Iraq, Russia and Ukraine are the leading three countries in the export of oranges and tangerines, Iraq, Russia and Saudi Arabia in the export of lemons, and Russia, Poland and Ukraine in the export of grapefruit.

While importing 67 thousand tons of citrus fruits in Turkey in 2019, it is seen that orange takes first place in imports with a share of 63%. Orange is followed by tangerine with 33%, lemon with 3% and grapefruit with 1%, respectively. When the data of the last 5 years are examined; It is observed that total citrus imports decreased by 5%

compared to 2015. While the highest decrease was seen in grapefruit imports with a rate of 67%, the only increase was seen in tangerine imports with a share of 15%.

While the most important importing country for Turkey's orange and tangerine imports in 2019 was the TRNC (Turkish Republic of Northern Cyprus), the TRNC and Brazil for lemons and China, TRNC and South Africa for grapefruit (OrduTB, 2021).

2. CONTENTS AND STUDIES OF *CITRUS* GENUS

Citrus fruit, one of the most popular fruits in the world, is used in gastronomy due to its attractive appearance, characteristic flavors, tastes and aromas and it is used in the field of basic sciences and the pharmaceutical industry due to its nutraceutical compounds (vitamins, phenolic compounds, flavonoids, etc.) and many health benefits (Smeriglio et al., 2019; Acoglu &Yolci Omeroglu, 2021; Gupta et al, 2021).

In addition to its beautiful appearance and delicious taste, the *Citrus* contains many important phytochemicals (Hashempour et al., 2013). One of these, which is known all over the world and has a very important place in the food industry, is ascorbic acid, that is, vitamin C (Hoyle & Santos, 2010).

Citrus genus produces and accumulates a wide variety of phytochemicals, including essential oils, carbohydrates, fiber, mineral, pectin, sugar, organic acids, quercetin, myricetin, rutin, tangeritin,

naringenin, naringin, nairutin, hesperidin, thiamine, niacin, riboflavin, hydroxybenzoic acid, hydrocinnamic acid, acetophenol, terpenoid, flavonoid, stilbene, tannin, vitamins A, B6, C, E, dietary fiber, potassium, folate, calcium, phosphorus, magnesium, copper, pantothenic acid, coumarins, alkaloids, limonoids, carotenoids, phenol acids (Kim et al., 2008; Okwu, 2008; Fasola et al., 2011; Lv et al., 2015; Pallivi et al., 2016; Chhikara et al., 2018; Acoglu & Yolci Omeroglu, 2021; Kundu et al., 2021).

The total vitamin C value in Citrus is the sum of ascorbic acid and dehydroascorbic acid (Magwaza et al., 2017). Vitamin C is found naturally in a variety of fruits and vegetables. This water-soluble vitamin cannot be synthesized by human metabolism (Chebrolu et al., 2012). It is involved in the formation of collagen, the primary component of connective tissue in the body (Sicari et al., 2018). Many studies are showing that vitamin C has properties that protect against neurodegeneration, fight cardiovascular diseases, and prevent cancer (Li & Schellhorn, 2007; Hoyle & Santos, 2010). Vitamin C, which has high antioxidant properties and important tasks in protecting against diseases, has a very important place in human nutrition. The recommended daily intake of vitamin C in healthy people is 100-120 mg/day (RDA) (Naidu, 2003). Orange juice in a 200 mL glass meets 30-80% daily vitamin C needs (Magwaza et al., 2017).

Ascorbic acid is a secondary compound that helps the antioxidant capacity of plant tissues in stress environments, as well as acting as a reducing agent in biochemical reactions (Fotopoulos et al., 2008). It acts

as a cofactor for enzymes and is also involved in the regulation of genes involved in defense (Magwaza et al., 2017). It has been reported that there are generally four biosynthetic pathways for the biosynthesis of ascorbic acid in different plants. These biosynthetic pathways are L-galactose, L-gulose, myoinositol and D-galacturonic acid pathways. The L-galactose pathway is generally preferred in citrus. The ascorbic acid content in citrus can be affected by many factors (climatic conditions, fruit maturity, etc.) (Zheng et al., 2021).

In one study, using Cyclic voltammetry, Limau kapas (*Citrus aurantiifolia* (Christm.) Swingle), limau kasturi (*Citrofortunella x mitis* (Blanco) J.W.Ingram & H.E.Moore), limau manis (*C. sinensis*) and lemons (*C. limon*) vitamins were compared and the highest vitamin C was found in lemon, while the lowest vitamin C was found in limau manis (approximately 28% lower) (Hoyle & Santos, 2010). In a study, *Citrus deliciosa* Ten. and *Citrus unshiu* (Yu.Tanaka ex Swingle) were used and the highest ascorbic acid value was found in *C. deliciosa* with a value of 1.887 ± 0.21 g/100 g (Piga et al., 2002).

Free radicals are produced as a normal part of the metabolism in auto-oxidant reactions triggered by mitochondrial activities, enzyme reactions, aging and cellular disruptions during respiration. Metabolism can neutralize these free radicals and progress in balance, but external factors such as environmental pollutants, ultraviolet light, smoking, alcohol intake cause oxidative stress. As a result, free radicals are overproduced, oxidative stress occurs, chain reactions begin, and then it can cause pathophysiological damage such as neurodegenerative

disorders, cardiovascular diseases, cell and tissue damage, diabetes, cancer, Alzheimer, and the functioning of metabolism is impaired (Lee et al., 2004; Fasola et al., 2011; Olatunya & Akintayo, 2017; Irawaty & Ayucitra, 2018).

A balanced diet consisting of antioxidant-rich plant sources can prevent the formation of pathophysiological disorders caused by free radicals (Irawaty & Ayucitra, 2018). Plant polyphenols, due to their high antioxidant activities, play an important role against chronic diseases such as Type-2 diabetes, heart disease, and various types of cancer (Zhang et al., 2014). Alkaloids, cyanogenic glycosides, flavonoids, terpenoids and phenolic compounds are all included in plant polyphenols (Okwu, 2008). Phenolic compounds are powerful antioxidants that can minimize or dampen the damage caused by free radicals, which prevent the oxidation of fatty acids and oils, as well as their ability to donate hydrogen atoms or electrons (Kim et al., 2008). Although natural antioxidants are found in almost all edible plants, some plants are significantly higher (Irawaty & Ayucitra, 2018). Plant phenolics are not only found in the edible parts of the plant, but also other parts of the plant (Rafiq et al., 2018). Plant-derived phenolic compounds play a role in many mechanisms such as deactivation of procarcinogens, maintenance of DNA repair, and inhibition of N-nitrosamine formation (Kim et al., 2008). Phenolic compounds are effective in the quality, color, taste, aroma and nutritional value of the fruit and have a very important role in human health due to their antioxidant properties. The phenolic content and density of fruits are

affected by environmental factors and post-harvest processing conditions (Benvenuti et al., 2004; Pellati et al., 2004; Hashempour et al., 2013; Oh et al., 2013; Olatunya & Akintayo, 2017).

Flavonoids are powerful antioxidants distributed in different parts of plants, which have an important role in protecting both plants and humans against many diseases (Montanari et al., 1998; Tapas et al., 2008; Sammani et al., 2021). Although flavonoids are considered non-nutritive chemicals, they have anti-inflammatory, anti-allergic, antimutagenic, anticarcinogenic, antibacterial, antiviral potential and take part in the expression of genes (Anwar et al., 2008; Zhao et al., 2017; Raeessi-Babaheydari et al., 2021). In addition, flavonoids are involved in many functions such as pigmentation in flowers, protection from the damage of insects and microorganism (Juca et al., 2020). Methanol extracts of citrus peels are rich in flavones and glycosylated flavanones, while hydrolyzed citrus peel extracts are rich in flavonols and phenolic acids (Bocco et al., 1998).

In citrus, there are higher amounts of flavonoids in the peel and fruit than in other parts (Senevirathne et al., 2009). Since citrus genus contains many important flavonoids such as hesperidin, nariutin, naringin, catechin, neohesperidin, it is thought to have anticarcinogenic, anti-inflammatory, antiallergic, antiviral, antitumor effects, and many studies are carried out in this area (Zheng et al., 2021).

The main problem of freshly squeezed citrus juices is the bitter feeling, mainly due to naringin, which is found in the fruit skin and is easily

dissolved in the juice thanks to its high solubility (Ziyatdinova et al., 2020). Naringenin is a flavonoid that is generally consumed by humans through citrus. It has been reported to induce cytotoxicity and apoptosis in various human cancer cells (Raeessi-Babaheydari et al., 2021).

Limonoids are intensely oxygenated, modified triterpenes that predominate in citrus fruits (Patil et al., 2017; Adenaike & Abakpa, 2021). Limonin and nominene are common citrus limonoids (Sun et al., 2005). Limonoids exhibit a wide variety of biological properties, including anticancer, antibacterial, antifungal, antimalarial, and antiviral activities (Tundis et al., 2014; Adenaike & Abakpa, 2021). Limonoids have the potential to inhibit colon cancer, ovarian cancer and neuroblastoma and inhibit the growth of estrogen receptor negative and positive human breast cancer cells (Patil et al., 2017; Adenaike & Abakpa, 2021).

Hesperidin is the most abundant flavanone glycoside from citrus peels. It can maintain vascular integrity and reduce vascular fragility, anti-inflammatory and immunomodulatory effects, and inhibit low-density lipoprotein (LDL) oxidation (Cirico & Omaye, 2006; Yeh et al., 2007, Londoño-Londoño et al., 2010).

Pectin is an acidic and negatively charged complex polysaccharide with a high molecular mass between 50-250 kDa, found in the primary cell wall and non-toxic (Jayani et al., 2005, Chen et al., 2021). There are 3 main types in plant cell walls: homogalacturonan, Rhamnogalacturonan, Rhamnogalacturonan-II (Ridley et al., 2001).

Although pectin is found in most plant cell walls, it is most commonly found in citrus fruits (lime, lemon, and grapefruit, orange) (Fasola et al., 2011). It is frequently used as a stabilizer, thickener, and emulsifier in many products, especially in the food (especially in jams, jellies) and beverage industry (Grassino et al., 2018; Chen et al., 2021). Pectin plays a role in reducing the fat in the blood, preventing the growth of cancer cells and metastasis (Chen et al., 2021). *Citrus* peels contain 20-35% pectin, apple pulp contain 10-15% pectin, sugar beet contain 5-8% pectin, and potato contain 2-5% pectin. Factories producing fruit juices produce large amounts of fruit peel waste and this waste can be used in pectin extraction (Rajulapati et al., 2021).

Carotenoids (carotenes), which are fat-soluble hydrocarbons, are found in green leaves, yellow and red fruits, and the roots of many plants (Walia et al., 2019). The pigment found in many fruits and vegetables are carotenoids and chlorophylls (López-Muñoz et al., 2015). *Citrus* contains many carotenoid patterns (Dugo & Giuffrida, 2011; Adenaike & Abakpa; 2021). The overall orange color of *Citrus* is due to the main carotenoids, xanthophylls, violaxatin, β-cryptoxanthin, anteroxanthin (Zacarías-García et al., 2021). The colors of citrus fruits are determined by carotenoids and chlorophylls, which tend to accumulate and deteriorate during ripening (Tadeo et al., 2020). They cannot be synthesized by animals. The most abundant carotenoids in fruits and vegetables are lutein, zeaxanthin, lycopene, and pro-vitamin A carotenoids, α- and β-carotene, and β-cryptoxanthin (Adenaike & Abakpa, 2021).

The acylation of xanthophylls with fatty acids increases their lipophilic character and is a very important requirement for their storage in chromoplasts (Mariutti & Mercadante, 2018). Carotenoids are important in the prevention of cancer and cardiovascular diseases due to their antioxidant and immunological properties (Rao & Rao, 2007). Chlorophylls decrease with maturation and the amount of carotenoids increases (López-Muñoz et al., 2015).

In a study, ascorbic acid content, total phenolic content and total carotenoid content experiments were performed with orange, Jaffa orange, grapefruit, pink grapefruit, Florida orange, apple, pineapple, and the highest ascorbic acid content was 1385 ± 36 μM in orange. Total phenolic content was found in orange with 755 ± 18 μg/mL of gallic acid equivalents, while the highest total carotenoid content was found in pink grapefruit with 8.3 ± 2.0 μg/mL of β-carotene equivalents (Gardner et al., 2000).

In a study, orange juice and orange wine of oranges of Kozan variety were compared. Two hydroxybenzoic acids; gallic and protocatechuic acid, were detected in orange juice and wine. Ferulic acid was the most dominant hydroxycinnamic acid in orange juice (24.06 mg/L) and wine (9.91 mg/L), as it accounted for the largest proportion of the total hydroxycinnamic acids contents. The EC_{50} value of orange juice (0.31 mg/mL) was found lower than orange wine (0.46 mg/mL). EC_{50} is inversely related to the antioxidant capacity of a compound, as it expresses the amount of antioxidants needed to decrease the radical

concentration by 50%. The lower EC_{50} value the higher the antioxidant activity of a compound (Brand-Williams et al., 1995; Kelebek et al., 2009).

In a study, in Trolox Equivalent Antioxidant Capacity (TEAC), the Ferric Reducing Antioxidant Power (FRAP) experiments of 10 different *Citrus* species, the highest value in the TEAC experiment was observed in *Citrus reticulata* × *Citrus paradisis* with 43.85 ± 1.2 µmol Trolox/g fresh weight. In the FRAP experiment, the highest value was observed in the *C. reticulata* × *C. paradisis* species with 57.72 ± 0.4 µmol Fe (II)/g fresh weight (Ramful et al., 2010).

In a study, electron-beam irradiation was applied to *C. unshiu* pulp, and its antioxidant activity was investigated. The total phenolic content of 70% ethanol extracts increased from 0.086 mg/g in the non-irradiated control to 0.096 mg/g at a radiation dose of 37.9 kGy (Kim et al., 2008). In a study with *C. unshiu*, *C. reticulata*, *C. sinensis*, *Citrus changshanensis* K.S. Chen et C.X., the highest total phenolic content was found in *C. changshanensis* with 916 mg CAE/100 g FW. The highest total flavonoids were found in 713 mg RE/100 g FW and the most carotenoids were found in *C. reticulata* with 1.36 mg BCE/100 g FW. The most ascorbic acid was found in *C. reticulata* with 45.3 mg/100g FW (Fresh Weight) (Abeysinghe et al., 2007).

In a study, as a result of the analysis of *Citrus lumia* Risso albedo with RP-LC-DAD-FLU, major phenol compound was found chlorogenic acid with 151.512 ± 4.842 mg/100g FW, major flavon was found

eriocitrin with 1012.407 ± 22.764 mg/100g FW, major flavonol was found in Quercetin-3-O-rutinoside (Rutin) with 10.923 ± 0.358. In the same study, FRAP, ABTS, ORAC, DPPH experiments were carried out. The results suggest that the extract acts as a powerful scavenger of different free radicals, with primary antioxidant activity probably depending on the reducing ability of hydroxylated phenolic structures and glycosylation degree (Barreca et al., 2016; Smeriglio et al., 2018; Smeriglio et al., 2019).

In a study, *C. aurantium* and *C. reticulata* immature (green), semimature, (yellow), commercial mature (orange), total phenolic content was found in *C. reticulata* immature. In the total flavonoid content experiment, the highest value was found in *C. reticulata* semimature (Moulehi et al., 2012). Seven flavonoids were identified and measured in the hot water extract of immature kumquat (*Citrus japonica* var. *margarita* (Lour.) Guillaumin) (mg/100 g fresh fruit): 30,50-di-Cb-glucopyranosylphloretin (DGPP, 285.9 ± 2.9 mg/ 100 g), acacetin 8-C-neohesperidoside (margariten, 136.2 ± 2.6 mg/100 g), acacetin 6-C-neohesperidoside (izomargariten, 119.1 ± 1.8 mg/100 g), apigenin 8-C-neohesperidoside (16.9 ± 0.1 mg/100 g), poncirin (izosakuranetin 7-O-neohesperidoside, 5.1 ± 0.1 mg/100 g) ve rhoifolin (apigenin 7-O neohesperidoside, 2.0 ± 0.1 mg/100 gr). Antioxidant activity, total phenolic content and identified flavonoids increased when immature kumquat was dried at 110 and 130 °C for 0.5 h (Lou et al., 2015). In one study, 261 ± 9 μM Trolox equivalents (TE) were found in the DPPH experiment with *C. limetta* juice, 1446 ± 30 μM

Trolox equivalents (TE) in the ABTS experiment, and 318 ± 8 μM Trolox equivalents (TE) in the FRAP experiment. In the same study, the major compound hesperidin was found with a value of 4.29 ± 0.53 mg/L in HPLC–DAD–ESI-MS/MS analysis (Barreca et al., 2011). In a study of *C. aurantium* with two cultivars (cv "Morocco Sour Orange (MSO)" (originated from Morocco), and "United Sour Orange (USO)"), the total phenolic content of MSO (584.2 ± 11.4 mg GAE) /100 g FW) was found to be higher than the total phenolic content of USO (113.8 ± 4.1 mg GAE/100 g FW). In terms of total flavonoid content, MSO (485.2 ± 19.4 mg CE/100 g FW) is higher than USO (59.2 ± 2.3 mg CE/100 g FW). In the DPPH experiment, MSO showed more activity with a value of 13.31 ± 0.55 μmol TE/g FW (Wen et al., 2021). In a study, DPPH experiment was performed with polysaccharides isolated from *C. aurantium* and it was found that it showed a weak antioxidant activity (Wang et al., 2014).

In a study, high speed drying (HSD) and freeze drying (FD) methods of *Citrus* genus were dried and their flavonoid content was examined. Hesperidin was found as the major compound in both methods, and 367.45 ± 3.91 mg/100 g was found in the FD method, while it was found to be mg/100 g in the HSD method. According to the result of the study, it was found that the amount of flavonoids was preserved more since it was dried with the FD method (Senevirathne et al., 2009).

In a study, the flavonoids of *C. grandis, C. limon, C. sinensis* and *Citrus tangerina* Yu.Tanaka were analyzed by UPLC-PDA. Naringin was found in *C.* grandis with the major compound 4508.22 ± 1577.02

mg/kg. Hesperidin was found in *C. tangerina* with the major compound 7977.62 ± 845.92 mg/kg. Hesperidin was found in *C. sinensis* with the major compound 7397.70 ± 1193.59 mg/kg. Eriocitrin was found in *C. limon* with the major compound 4704.73 ± 1229.95 mg/kg (Zhao et al., 2017).

In a study, the essential oils of the fresh and dried bark of three species of *Citrus* found in Nigeria were extracted and their chemical components and antioxidant properties were investigated.

In the study, the highest oil rate was observed in dried tangerine with 3.33%, while the lowest oil rate was observed in lime with 1.33%. In the chemical component analysis, the most limonene was found in all 3 species, and different terpene classes were also found. Dried samples were found to have higher terpene groups than fresh samples. DPPH free radical scavenging activity was used in the antioxidant experiment, and the highest activity was observed in dried species. According to the result of the study, it was found that *Citrus* species can work from dried samples stored in the right conditions rather than being evaluated as fresh for use in many sectors so that more efficiency can be obtained and it does not lose value for metabolic health (Olatunya & Akintayo, 2017).

In a study, two varieties of grapefruits (*C. paradisi*) (Marsh and Star Ruby), phytochemical properties and antioxidant potentials were studied and it was found that Marsh variety had the highest TSS (Total Soluble Solids) value (13.44%), while Star Ruby value was found to

have 10.78%. The ascorbic acid concentration in Marsh and Star Ruby grapefruit (680.03 ± 7.03 and 455.55 ± 4.02 mg/L, respectively) was found to be similar to the ascorbic acid content found in yellow oranges grown in the same geographic area. In the same study, HPLC analysis was performed with the juice of two varieties and 5 different flavanones were determined: narirutin (naringenin 7-β-rutinoside), naringin (naringenin 7-β-neohesperidoside), hesperidin (hesperetin 7-β-rutinoside), neohesperedin (hesperetin 7-β- neohesperidoside) and poncirin (isosakuranetin-7-oneohesperidoside). While the total phenolic content was found in Star Ruby with 167.22 ± 0.98 mg/L in the experiment, the amount of ascorbic acid was observed with 660.03 ± 7.03 mg/L in Marsh variety (Sicari et al., 2018).

In a study, the antioxidant activity of the hexane, ethyl acetate, water residue of the bark of Kaffir lime (*Citrus hystrix* DC.) was investigated. The IC_{50} values of DPPH radical scavenging activity observed in ethyl acetate and water residue were found with 0.029 ± 0.001 mg/mL. The ability of the fractions of *C. hystrix* peel to chelate Fe^{2+} presented as IC50, the fraction of ethyl acetate exhibited the lowest IC_{50} value of 0.117 ± 0.014, whereas the fraction of hexane and water residue have IC_{50} values of 18.502 ± 2.154 and 1.188 ± 0.474 mg/mL, respectively. The potential inhibitions of samples on the α-amylase inhibitory activity of IC_{50} values of the hexane fraction, ethyl acetate fraction and water residue were observed 125.00, 0.09, and 1.53 mg/mL, respectively. The results of the study showed that ethyl acetate was the

most effective solvent for removing phytochemicals from the ethanolic crude extract of *C. hystrix* bark (Irawaty & Ayucitra, 2018).

CONCLUSION

Citrus is the most consumed fruit in the world and is used in many sectors thanks to the chemicals useful for metabolism. Citrus is very valuable because not only the fruit is used, but also other waste parts can be used. Citrus grown in many countries of the world helps both the country's economy and people's health. With each new contribution, a new feature of citrus fruit is brought to the literature, and it is thought that it will be used in many more studies. More specific studies are needed on the parts of citrus that cannot be considered as waste.

REFERENCES

Abeysinghe, D.C., Li, X., Sun, C., Zhang, W., Zhou, C., & Chen, K. (2007). Bioactive compounds and antioxidant capacities in different edible tissues of *Citrus* fruit of four species. Food Chemistry, 104: 1338-1344.

Acoglu, B. & Yolci Omeroglu, P. (2021). Effectiveness of different types of washing agents on reduction of pesticide residues in orange (*Citrus sinensis*). LWT - Food Science and Technology, 47, 111690.

Adenaike, O. & Abakpa, G.O. (2021). Antioxidant compounds and health benefits of *Citrus* fruits. European Journal of Nutrition & Food Safety, 13(2): 65-74.

Amutha, R.A., Kavusik, T.I., & Sudha, A. (2017). Analysis of bioactive compounds in *Citrus* fruit peels. International Journal of Scientific Research and Review, 6(12): 18-27.

Anwar, F., Naseer, R., Bhanger, M.I., Ashraf, S., Talpur, F.N., & Aladededune, F.A. (2008). Physicochemical characteristics of *Citrus* seeds and oils from Pakistan. J. Am. Oil Chem. Soc., 85: 321-330.

Barreca, D., Bellocco, E., Caristi, C., Leuzzi, U., & Gattuso, G. (2011). Flavonoid profile and radical-scavenging activity of Mediterranean sweet lemon (*Citrus limetta* Risso) juice. Food Chemistry, 129: 417-422.

Barreca, D., Laganà, G., Leuzzi, U., Smeriglio, A., Trombetta, D., & Bellocco, E. (2016). Evaluation of the nutraceutical, antioxidant and cytoprotective properties of ripe pistachio (*Pistacia vera* L., variety Bronte) hulls. Food Chemistry, 196: 493-502.

Benvenuti, S., Pellati, F., Melegari, M., & Bertelli, D. (2004). Polyphenols, anthocyanins, ascorbic acid, and radical scavenging activity of *Rubus, Ribes*, and *Aronia*. J. Food Scie. 69: 164-169.

Bocco, A., Cuvelier, M.E., Richard, H., & Berset, C. (1998). Antioxidant activity and phenolic composition of *Citrus* peel and seed extracts. Journal of Agricultural and Food Chemistry, 46: 2123–2129.

Brand-Williams, W., Cuvelier, M.E., & Berset, C. (1995). Antioxidative activity of phenolic composition of commercial extracts of sage and rosemary. LWT, 28: 25-30.

Cerda, J.J., Normann, S.J. & Sullivan, M.P. (1994). Inhibition of atherosclerosis by dietary pectin in microswine with sustained hypercholesterolemia. Circulation, 89: 1247-1253.

Chebrolu, K.K., Jayaprakasha, G.K., Yoo, K.S., Jifon, J.L., & Patil, B.S. (2012). An improved sample preparation method for quantification of ascorbic acid and dehydroascorbic acid by HPLC. LWT – Food Sci. Technol., 47: 443-449.

Chekani, R., Akrami, R., Ghiasvand, Z., Chitsaz, H., & Jorjani, S. (2021). Effect of dietary dehydrated lemon peel (*Citrus limon*) supplementation on growth, hemato-immunolological and antioxidant status of rainbow trout (*Oncorhynchus mykiss*) under exposure to crowding stress. Aquaculture, *539*, 736597.

Chen, T.T., Zhang, Z.H., Wang, Z.H., Chen, Z.L., Ma, H., & Yan, J.K. (2021). Effects of ultrasound modification at different frequency modes on physicochemical, structural, functional, and biological properties of *Citrus* pectin. Food Hydrocolloids, 113, 106484.

Chhikara, N., Kour, R., Jaglan, S., Gupta, P., Gat, Y., & Panghal, A. (2018). *Citrus medica*: Nutritional, phytochemical composition and health benefits–a review. Food Funct., 9(4): 1978-1992.

Cirico, T.L. & Omaye, S.T. (2006). Additive or synergetic effects of phenolic compounds on human low density lipoprotein oxidation. Food and Chemical Toxicology, 44(4): 510-516.

Dugo, P. & Giuffrida, D. (2011). Carotenoids of *Citrus* Oils. In G. Dugo & L. Mondello (Eds.), *Citrus* Oils: Composition, Advanced Analytical Techniques, Contaminants, and Biological Activity Boca Raton: CRC Press. pp. 445–461.

Ehiobu, J.M., Idamokoro, M.E., & Afolayan, A.J. (2021). Phytochemical content and antioxidant potential of leaf extracts of *Citrus limon* (L.) Osbeck collected in the Eastern Cape Province, South Africa. South African Journal of Botany, 141, 480486.

Ersus, S. & Cam, M. (2007). Determination of organic acids, total phenolic content, and antioxidant capacity of sour *Citrus aurantium* fruits. Chemistry of Natural Compounds, 43(5): 607–609.

Fasola, T.R., Oloyode, G.K., & Aponjolosun, B.S. (2011). Chemical composition, toxicity and antioxidative activities of essential oils of stem bark of Nigerian species of Guava (*Psidium guajava* Linn). Experimental and Clinical Sciences, 10: 34-43.

Fotopoulos, V., De Tullio, M.C., Barnes, J., & Kanellis, A.K. (2008). Altered stomatal dynamics in ascorbate oxidase over-expressing tobacco plants suggest a role for dehydroascorbate signalling. J. Exp. Bot., 59: 729-737.

Garcia Beltran, J.M., Espinosa, C., Guardiola, F.A., & Esteban, M.A. (2017). Dietary dehydrated lemon peel improves the immune but not the antioxidant status of gilthead seabream (*Sparus aurata*). Fish Shellfish Immunol., 64: 426-436.

Gardner, P.T., White, T.A.C., McPhail, D.B., & Duthie, G.G. (2000). The relative contributions of vitamin C, carotenoids and phenolics to the antioxidant potential of fruit juices. Food Chemistry, 68: 471-474.

Grassino, A.N., Barba, F.J., Brncic, M., Lorenzo, J.M., Lucini, L., & Brncic, S.R. (2018). Analytical tools used for the identification and quantification of pectin extracted from plant food matrices, wastes and by-products: A review. Food Chem, 266: 47-55.

Guo, J.J., Gao, Z.P., Xia, J.L., Ritenour, M.A., Li, G.Y., & Shan, Y. (2018). Comparative analysis of chemical composition, antimicrobial and antioxidant activity of citrus essential oils from the main cultivated varieties in China. LWT-Food Science and Technology, 97: 825-839.

Gupta, A.K., Mishra, P., Senapati, M., & Sahu, P.P. (2021). A novel electrochemical device for naringin quantification and removal from bitter variety of *Citrus* fruits. Journal of Food Engineering, 306, 110637.

Hashempour, A., Sharifzadeh, K., Bakhshi, D., Ghazvini, R.F., Ghasemnezhad, M., & Mighani, H. (2013). Variation in total phenolic, ascorbic acid and antioxidant activity of *Citrus* fruit of six species cultivated in north of Iran. International Journal of Agriculture: Research and Review, 3(1): 1-5.

Hosseini, S.S., Khodaiyan, F., & Yarmand, M.S. (2016). Optimization of microwave assisted extraction of pectin from sour orange peel and its physicochemical properties. Carbohydrate Polymers, 140: 59-65.

Hoyle, C.H.V. & Santos, J.H. (2010). Cyclic voltammetric analysis of antioxidant activity in citrus fruits from Southeast Asia. International Food Research Journal, 17: 937-946.

Irawaty, W. & Ayucitra, A. (2018). Assessment on antioxidant and *in vitro* antidiabetes activities of different fractions of *Citrus hystrix* Peel. International Food Research Journal, 25(6): 2467-2477.

Javed, S., Ahmad, R., Shahzad, K., Nawaz, S., Saeed, S., & Yasar, S. (2013). Chemical constituents' antimicrobial and antioxidant activity of essential oil of *Citrus limetta* var. *mitha* (sweetling peel) in Pakistan. African Journal of Microbiology Research, 7(24): 3071-3077.

Jayani, R.S., Saxena, S., & Gupta, R. (2005). Microbial pectinolytic enzymes: A review. Process Biochem, 40(9): 2931–2944.

Juca, M.M., Filho, F.M.S.C., Almeida, J.C., Mesquita, D.D., Barriga, J.R.D., Dias, K.C.D.F., Barbosa, T.M., Vasconcelos, L.C., Leal, L.K.A.M., Ribeiro, J.E., & Vasconcelos, S.M.M. (2020). Flavonoids: Biological activities and therapeutic potential. Natural Product Research., *3*4: 692–705.

Kähkönen, M.P. & Heinonen, M. (2003). Antioxidant activity of anthocyanins and their aglycons. Journal of Agricultural and Food Chemistry, 51: 628-633.

Karabıyıklı, Ş., Degirmenci, H., & Karapınar, M. (2014). Inhibitory effect of sour orange (*Citrus aurantium*) juice on *Salmonella Typhimurium* and *Listeria monocytogenes*. LWT-Food Science and Technology, 55*:* 421-425.

Kelebek, H., Selli, S., Canbas, A., & Cabaroglu, T. (2009). HPLC determination of organic acids, sugars, phenolic compositions and antioxidant capacity of orange juice and orange wine made from a Turkish cv. Kozan. Microchemical Journal, 91: 187-192.

Kim, J.W., Lee, B.C., Lee, J.H., Nam, K.C., & Lee, S.C. (2008). Effect of electron-beam irradiation on the antioxidant activity of extracts from *Citrus unshiu* pomaces. Radiation Physics and Chemistry, 77: 87-91.

Kundu, D., Banerjee, S., Karmakar, S., & Banerjee, R. (2021). Valorization of *Citrus lemon* wastes through biorefinery approach: An industrial symbiosis.

Bioresource Technology Reports, 15: 100717 https://doi.org/10.1016/j.biteb.2021.100717

Lee, J., Koo, N., & Min, D.B. (2004). Reactive oxygen species, aging, and antioxidative nutraceuticals. Comprehensive Reviews in Food Science and Food Safety, 3(1): 21-33.

Li, Y. & Schellhorn, H.E. (2007). New developments and novel therapeutic perspectives for vitamin C. Journal of Nutrition, 137: 2171-2184.

Londoño-Londoño, J., Rodrigues de Lima, V., Lara, O., Gil, A., Pasa, T.B.C., Arango, G.J., & Pineda, J.R.R. (2010). Clean recovery of antioxidant flavonoids from *Citrus* peel: Optimizing an aqueous ultrasound-assisted extraction method, Food Chemistry, 119: 81-87.

López-Muñoz, G.A., Antonio-Pérez, A., & Díaz-Reyes, J. (2015). Quantification of total pigments in citrus essential oils by thermal wave resonant cavity photopyroelectric spectroscopy. Food Chemistry, 174: 104-109.

Lou, S., N., Lai, Y.C., Huang, J.D., Ho, C.T., Ferng, L.H.A., & Chang, Y.C. (2015). Drying effect on flavonoid composition and antioxidant activity of immature kumquat. Food Chemistry, 171: 356-363.

Lv, X., Zhao, S., Ning, Z., Shu, Y., Tao, O., Xiao, C., Lu, C., & Liu, Y. (2015). *Citrus* fruits as a treasure trove of active natural metabolites that potentially provide benefits for human health. Chem Cent J., 24(9): 68.

Magwaza, L.S., Mditshwa, A., Tesfay, S.Z., & Opara, U.L. (2017). An overview of preharvest factors affecting vitamin C content of *Citrus* fruit. Scientia Horticulturae, 216: 12-21.

Mariutti, L.R.B. & Mercadante, A.Z. (2018). Carotenoid esters analysis and occurrence: What do we know so far? Archives of Biochemistry and Biophysics, 648: 36-43.

Mazza, G. & Miniati, E. (1993). Anthocyanins in fruit, vegetables and, grains. Boca Raton, FL: CRC Press Inc.

Montanari, A., Che, J., & Widmer, W. (1998). *Citrus* Flavonoids: A Review of Past Biological Activity Against Disease, In: J.A. Manthey, B.S. Buslig (Eds.), Flavonoids in the living system, Springer, US, Boston, MA, 1998, pp: 103-116.

Moulehi, I., Bourgou, S., Ourghemmi, I., & Tounsi, M.S. (2012). Variety and ripening impact on phenolic composition and antioxidant activity of mandarin (*Citrus reticulate* Blanco) and bitter orange (*Citrus aurantium* L.) seeds extracts. Industrial Crops and Products, 39: 74-80.

Naidu, K.A. (2003). Vitamin C in human health and disease is still a mystery? An Overview. J. Nutr., 2: 7-16.

Natella, F., Nardini, M., Di Felice, M., & Scaccini, C. (1999). Benzoic and cinnamic acid derivatives as antioxidants structure–activity relation. Journal of Agricultural and Food Chemistry, 47: 1453-1459.

Oh, J., Jo, H., Cho, A.R., Kim, S.J., & Han, J. (2013). Antioxidant and antimicrobial activities of various leafy herbal teas. Food Control, 31(2): 403-409.

Okwu, D.E. (2008). *Citrus* fruits: A rich source of phytochemicals and their roles in human health. Int. J. Chem. Sci., 6(2), 451-471.

Olatunya, A.M. & Akintayo, E.T. (2017). Evaluation of the effect of drying on the chemical composition and antioxidant activity of the essential oil of peels from three species of citrus group. International Food Research Journal, 24(5): 1991-1997.

OrduTB, (2021). Narenciye Report. https://www.ordutb.org.tr/wp-content/uploads/2021/01/Narenciye-Raporu.pdf (Access date: 15.09.2021)

Pallavi, M., Ramesh, C.K., Krishna, V., & Parveen, S. (2016). Peels of *Citrus* fruits: A potential source of anti-inflammatory and anti-nociceptive agents. Pharmacognosy Journal, 10(6): 172-178.

Patil, B.S., Jayaprakasha, G.K., & Murthy, K.N.C. (2017). Beyond vitamin C: The diverse, complex health-promoting properties of *Citrus* fruits. *Citrus* Research and Technology, 38(1): 107-121.

Pellati, F., Benvenuti, S., Magro, L., Melogari, M., & Soragni, F. (2004). Analysis of phenolic compounds and radical scavenging activity of *Echinacea* spp. Journal of Pharmaceutical and Biomedical Analysis, 35: 289- 301.

Piga, A., Agabbio, M., Gambella, F., Nicoli, M.C. (2002). Retention of antioxidant activity in minimally processed mandarin and satsuma fruits. Lebensm.-Wiss. u.-Technol., 35: 344-347.

Raeessi-Babaheydari, E., Farhadian, S., & Shareghi, B. (2021). Evaluation of interaction between *Citrus* flavonoid, naringenin, and pepsin using spectroscopic analysis and docking simulation. Journal of Molecular Liquids, 339, 116763.

Rafiq, S., Kaul, R., Sofi, S.A., Bashir, N., Nazir, F., & Nayik, G.A. (2018). *Citrus* peel as a source of functional ingredient: A review. Journal of the Saudi Society of Agricultural Sciences, 17: 351-358.

Rajulapati, V., Dhillon, A., & Goyal, A. (2021). Enzymatically produced pectic-oligosaccharides from fruit waste of *Citrus reticulata* (mandarin) peels display cytotoxicity against colon cancer cells. Bioresource Technology Reports, 15, 100740.

Ramful, D., Bahorun, T., Bourdon, E., Tarnus, E., & Aruoma, O.I. (2010). Bioactive phenolics and antioxidant propensity of flavedo extracts of Mauritian citrus fruits: Potential prophylactic ingredients for functional foods application. Toxicology, 278: 75–87.

Rao, A.V. & Rao, L.G. (2007). Carotenoids and human health. Pharmacology Research, 55: 207-216.

Rapisarda, P., Bellomo, S. E., & Intrigliolo, F. (2001). Anthocyanins in Blood Oranges: Composition and Biological Activity. In S. G. Pandalai (Ed.). Recent Research Developments in Agricultural and Food Chemistry, Volume 5. pp: 217-230. Trivandrum, India: Research Signpost.

Rapisarda, P., Fabroni, S. Peterek, S. Russo, G., & Mock, H.P. (2009). Juice of New citrus hybrids (*Citrus clementine* Hort. ex Tan. *C. sinensis* L. Osbeck) as a source of natural antioxidants. Food Chemistry, 117, 212-218.

Ridley, B.L., O'Neill, M.A., & Mohnen, D. (2001). Pectins: Structure, biosynthesis, and oligogalacturonide-related signaling. Phytochemistry 57(6): 929-967.

Sammani, M.S., Clavijo, S., Figuerola, A., & Cerda, V. (2021). 3D printed structure coated with C18 particles in an online flow system coupled to HPLC-DAD for the determination of flavonoids in *Citrus* external peel. Microchemical Journal, 168, 106421.

Schmidt, E. (2010). Production of essential oils. In K. H. C. Baser & G. Buchbauer (Eds.), Handbook of essential oils: Science, technology, and applications. pp. 83–120. Boca Raton: CRC Press.

Senevirathne, M., Jeon, Y.J., Ha, J.H., & Kim, S.H. (2009). Effective drying of Citrus by-product by high speed drying: A novel drying technique and their antioxidant activity. Journal of Food Engineering, 92: 157-163.

Sicari, V., Pellicanò, T.M., Giuffrè, A.M., Zappia, C., Capocasale, M., & Poiana, M. (2018). Physical chemical properties and antioxidant capacities of grapefruit juice (*Citrus paradisi*) extracted from two different varieties. International Food Research Journal, 25(5): 1978-1984.

Singh, P., Shukla, R., Prakash, B., Kumar, A., Singh, S., Mishra, P.K., & Dubey, N.K. (2010). Chemical profile, antifungal, antiaflatoxigenic and antioxidant activity of *Citrus maxima* Burm. and *Citrus sinensis* (L.) Osbeck essential oils and their cyclic monoterpene, DL-limonene. Food and Chemical Toxicology, 48*:* 1734-1740.

Smeriglio, A., Alloisio, S., Raimondo, F. M., Denaro, M., Xiao, J., Cornara, L., & Trombetta, D. (2018). Essential oil of *Citrus lumia* Risso: Phytochemical profile, antioxidant properties and activity on the central nervous system. Food and ChemicalToxicology, 119: 407-416.

Smeriglio, A., Cornara, L., Denaro, M., Barreca, D., Burlando, B., Xiao, J., & Trombetta, D. (2019). Antioxidant and cytoprotective activities of an ancient Mediterranean *Citrus* (*Citrus lumia* Risso) albedo extract: Microscopic observations and polyphenol characterization. Food Chemistry, 279: 347–355.

Strano, M.C., Timpanaro, N., Allegra, M., Foti, P., & Pangallo, S. (2021). Effect of ozonated water combined with sodium bicarbonate on microbial load and shelf life of cold stored clementine (*Citrus clementina* Hort. ex Tan.). Scientia Horticulturae, 276, 109775.

Sun, C., Chen, K., Chen, Y., & Chen, Q. (2005). Contents and antioxidant capacity of limonin and nomilin in different tissues of *Citrus* fruit of four cultivars during fruit growth and maturation. Food Chemistry, 93: 599-605.

Suntar, I., Khan, H., Patel, S., Celano, R., & Rastrelli, L. (2018). An overview on *Citrus aurantium* L.: Its functions as food ingredient and therapeutic agent. Oxidative Medicine and Cellular Longevity, 7864269 https://doi.org/10.1155 /2018/7864269.

Tadeo, F.R., Terol, J., Rodrigo, M.J., Licciardello, C., & Sadka, A. (2020). Fruit Growth and Development. In M. Talon, M. G. Caruso, & F. Jr (Eds.). The Genus *Citrus.* (1st ed.). Elsevier. pp: 245-269.

Tapas, A., Sakarkar, D., & Kakde, R. (2008). Flavonoids as nutraceuticals: A review. Tropical J. Pharm. Res. *7*: 1089-1099.

Tundis, R., Loizzo, M.R., & Menichini, F. (2014). An overview on chemical aspects and potential health benefits of limonoids and their derivatives. Critical Reviews in Food Science and Nutrition, 54(2): 225-250.

Upadhyay, R.K., Divividi, P., & Ahmad, S. (2010). Screening of antibacterial activity of six plant essential oils against pathogenic bacterial strains. Asian Journal of Medical Sciences, 2(3): 152- 158.

Vitale, A., Aiello, D., Azzaro, A., Guarnaccia, V., & Polizzi, G. (2021). An eleven-year survey on field disease susceptibility of *Citrus* accessions to *Colletotrichum* and *Alternaria* species. Agriculture, 11(6): 536.

Walia, A., Gupta, A.K., & Sharma, V. (2019). Role of bioactive compounds in human health. Acta Scientific Medical Sciences., 3(9): 25-33.

Wang, H., Cao, G., & Prior, R. L. (1997). Oxygen radical absorbing capacity of anthocyanins. Journal of Agricultural and Food Chemistry, 45: 304-309.

Wang, Q.H., Shu, Z.P., Xu, B.Q., Xing, N., Jiao, W.J., & Yang, B.Y. (2014). Structural characterization and antioxidant activities of polysaccharides from *Citrus aurantium* L. International Journal of Biological Macromolecules, 67: 112-123.

Wang, R., Hassan, W., Ahmad, F.u.D., Jabeen, Q., Ahmed, H., & Iqbal, O. (2019b). *Citrus aurantium* ameliorates cisplatin-induced nephrotoxicity. BioMed Research International, 3960908. https://doi.org/10.1155/2019/3960908.

Wang, Y., Ji, S., Zang, N., Cao, J., Li, J., & Sun, C. (2019a). Identification of phenolic compounds from a unique *Citrus* species, finger lime (*Citrus australasica*) and their inhibition of LPS-induced NO-releasing in BV-2 cell line. Food and Chemical Toxicology, 129: 54–63.

Wen, L., He, M., Yin, C., Jiang, Y., Luo, D., & Yang, B. (2021). Phenolics in *Citrus aurantium* fruit identified by UHPLC-MS/MS and their bioactivities. LWT-Food Science and Technology, 147, 111671.

Wu, S., Li, M., Zhang, C., Tan, Q., Yang, X., Sun, X., Pan, Z., Deng, X., & Hu, C. (2021). Effects of phosphorus on fruit soluble sugar and citric acid accumulations in *Citrus*. Plant Physiology and Biochemistry, 160: 73-81.

Yeh, C.C., Kao, S.J., Lin, C.C., Wang, S.D., Liu, C.J., & Kao, S.T. (2007). The immunomodulation of endotoxin-induced acute lung injury by *hesperidin in vivo* and *in vitro*. Life Science, 80(20): 1821-1831.

Zacarías-García, J., Lux, P.E., Carle, R., Schweiggert, R.M., Steingass, C.B., Zacarías, L., & Rodrigo, M.J. (2021). Characterization of the Pale Yellow Petal/Xanthophyll Esterase gene family in citrus as candidates for carotenoid esterification in fruits. Food Chemistry, 342, 128322.

Zhang, Y., Sun, Y., Xi, W., Shen, Y., Qiao, L., Zhong, L., Ye., X., & Zhou, Z. (2014). Phenolic compositions and antioxidant capacities of Chinese wild mandarin (*Citrus reticulata* Blanco) fruits, Food Chemistry, 145: 674-680.

Zhao, Z., He, S., Hu, Y., Yang, Y., Jiao, B., Fang, Q., & Zhou, Z. (2017). Fruit flavonoid variation between and within four cultivated *Citrus* species evaluated by UPLC-PDA system. Scientia Horticulturae, 224: 93-101.

Zhao, Z., He, S., Hu, Y., Yang, Y., Jiao, B., Fang, Q., & Zhou, Z. (2017). Fruit flavonoid variation between and within four cultivated *Citrus* species evaluated by UPLC-PDA system. Scientia Horticulturae, 224: 93-101.

Zheng, H., Zhen, X.T., Chen, Y., Zhu, S.C., Ye, L.H., Yang, S.W., Wang, Q.Y., & Cao, J. (2021). In situ antioxidation-assisted matrix solid-phase dispersion microextraction and discrimination of chiral flavonoids from *Citrus* fruit via ion mobility quadrupole time-of-flight high-resolution mass spectrometry. Food Chemistry, 343, 128422. https://doi.org/10.1016/j.foodchem.2020.128422

Ziyatdinova, G., Yakupova, E., Guss, E., & Budnikov, H. (2020). The selective electrochemical sensing of naringin using electropolymerized ellagic acid film. J. Electrochem. Soc., 167: 107502.

Zou, Z., Xi, W., Hu, Y., Nie, C., & Zhou, Z. (2016). Antioxidant activity of *Citrus* fruits. Food Chemistry, 196: 885–896.

CHAPTER III

MANGO, MANGIFERIN AND HEALTH

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INTRODUCTION

Mango (*Mangifera indica*) is a valuable ornamental tree and also contributes to the protection of soil against erosion (Bokonon-Ganta et al., 2002). The leaves of the mango tree are used as ornamental in weddings and religious rituals (Kittiphoom, 2012). Besides, different medicinal benefits of mango are known (Bokonon-Ganta et al., 2002).

The products of the mango tree are mainly used as fruit, sweetener, medicinal, and wood. In terms of main agroforestry, mango is used in home gardens and silvo pastures (Bally, 2006).

The fruit of the mango tree is one of the most popular and important tropical products due to its particularly nutritional value and attractive flavor and it has the status of "king of fruits" (Singh et al., 2013; Biswas et al., 2015). The name of the 'mango' originates from the ancient Tamil word 'mangai' in the 16th century (Tharanathan et al., 2006). Mango fruit is grown in many countries of the world, mostly in tropical countries (Jahurul et al., 2015). Distributed in all tropical and subtropical regions (Kittiphoom, 2012). Mango is a fruit native to northeastern India and northern Burma, but it is stated to be grown in more than 90 countries today. Mango cultivation ranks second in tropical fruit production in the horticultural industry worldwide (Singh et al., 2013). Hundreds of varieties with marked differences in flavor properties are grown in different parts of the world (Pino et al., 2005). Products from mango fruits are nectar, syrup, puree, pickles, chutney and canned slices (Jahurul et al., 2015; Ajila et al., 2017).

Mango fruits are a source of protein, carbohydrates, fat, dietary fiber and energy, as well as micronutrients and phytochemicals that are important for human growth, development and health (Tharanathan et al., 2006; Jahurul et al., 2015).

It is stated that different parts of the mango tree have various medicinal properties according to Ayurvedic medicine (Parvez, 2016). Mango has been an essential nutrient in indigenous medicinal systems for over 4,000 years. Mangiferin, bioactive polyphenol compound, generally isolated from the mango tree and has been found in some plant species (Shah et al., 2010). It is stated that mangiferin is an antioxidant with superior properties such as antibacterial, hepatoprotective, antiviral, antioxidant, anticancer, immunomodulatory, anti-aging, antidiabetic and analgesic effects (Imran et al., 2017; Yang et al., 2020).

In this chapter, it is aimed to give general information about some properties of the mango tree, mango fruit, and mangiferin compound derived from mango and health effects.

1. GENERAL PROPERTIES OF MANGO TREE AND FRUIT

Mangifera indica or Mango is the species of the genus *Mangifera* and the order Sapindales in the Anacardiaceae family (Shah et al., 2010). As a tropical product, mango, which is grown on an area of approximately 3.7 million hectares worldwide, ranks second in terms of tropical products (Parvez, 2016). The mango tree, which has a long lifespan, can live for more than a hundred years (Tharanathan et al., 2006). This tree has a height ranging from 10-40 m and is an evergreen,

symmetrical tree. Its color ranges from green to yellow and red. (Tharanathan et al., 2006; Parvez, 2016). Its leaves can be in different shapes such as lanceolate, oblong, oval, round. It is also stated that the length of the petiole can vary from about 1 to 12 cm (Parvez, 2016).

The sizes of both male and hermaphrodite flowers range from between 6 to 8 mm. They are rarely stalky and have a sweet scent. Pollen grains are of variable shape and range in size from 20 to 35 microns (Parvez, 2016). Mango trees have great potential to form fruit (Tharanathan et al., 2006). Mango flowering is an important physiological event for fruit production (Ramírez & Davenport, 2010). The fruit of this tree is fleshy and drupe. It shows diversity significantly in fiber presence, size, shape, taste, color, flavor, and many other properties (Parvez, 2016). Mango morphologically has a single large seed surrounded by a meaty mesocarp (Tharanathan et al., 2006).

These fruits are described by thin peel, soft flesh with low fiber content, and tasty aroma. Its flavor is very nice and of very good quality with an ideal sugar/acid ratio (Tharanathan et al., 2006). Mango is a seasonal fruit that is eaten raw or ripe (Ajila et al., 2017; Kalra et al., 2018).

Normally, mangoes reach maturity 4-5 months after flowering. These fruits are harvested at a mature green phase and stored for normal ripening after harvest. When the mango is fully grown and ready to be picked, it is easily picked with a light pull. If the fruit does not break easily when pulled strongly, the fruit is unripe and should not be harvested. Generally, it takes 6-10 days for mangoes to mature at

ambient temperature, depending on the variety, environmental conditions, and mature and deteriorate within 15 days after harvest (Tharanathan et al., 2006).

There is great diversity in color, weight, and shape among mango varieties. Mangoes mature between 11 and 14 weeks after fruit set, depending on the variety and place of growth (Singh et al., 2013). Images of commercially available mangoes are given in Figure 1.

Figure 1: Commercial Mango (*Mangifera indica*) Fruits (Original by Demirhan)

The main nutritional components are found in the leaves, flowers, bark parts of the mango tree, as well as in the mango fruit, fruit pulp, fruit peel, and seeds (Jahurul et al., 2015).

Mango contains various phytochemicals and nutrients. Compounds such as polyphenols, omega-3, and omega-6 polyunsaturated fatty acids and pigment carotenoids can be found in the pulp and peel of the mango. It is stated that phytochemical and nutrient content varies among mango varieties (Parvez, 2016). The protein content of mango fruit varies between 0.5 and 1% on a fresh weight basis (Tharanathan et al., 2006).

2. OVERVIEW OF THE MANGIFERIN

2.1. General Properties of Mangiferin

Mangiferin ($C_{21}H_{25}NO_4$) is a a well-known natural C-glucosyl xanthone compound that is found at significant levels in higher plants and in the bark, leaves, and root parts of *Mangifera indica* (Kasbe et al., 2015; Imran et al., 2017; Yang et al., 2020). It is a secondary metabolite commonly found in natural products, was first discovered as a dyestuff produced from the roots of mango trees (Yang et al., 2020).

The chemical name of mangiferin is 1,3,6,7-tetrahydroxyxanthone-C2-β-D-glucoside. Its molecular weight and melting point (anhydrous) are 422.35 and 271°C, respectively (Sekar, 2015; Swaroop et al., 2018). The chemical structure of mangiferin is given in the Figure 2 (Daud et al., 2010).

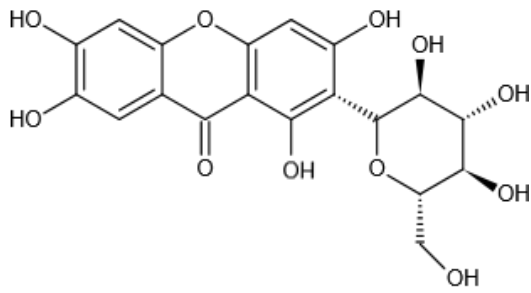

Figure 2: Chemical Structure of Mangiferin (Daud et al., 2010)

Four aromatic hydroxyl groups in the mangiferin molecule are responsible for the antiradical and antioxidant properties of mangiferin (Matkowski et al., 2013). It is a light-yellow crystalline powder and has low solubility in ethanol, methanol, and water (Swaroop et al., 2018).

This compound has a weak hydrophilic and lipophilic properties (Ma et al., 2014).

There are different methods such as soxhlet extraction, subcritical extraction, and pressurized liquid extraction for the extraction of mangiferin from various parts of the mango tree (Khurana et al., 2016).

2.2. Mangiferin and Health Effects

Mangiferin is a natural polyphenol and various biological effects (Matkowski et al., 2013). It has been stated that the oral bioavailability of mangiferin is only 1.2% (Han et al., 2010). In a study to increase limited oral bioavailability, it was observed that the water solubility of mangiferin improved by 6.2 times, and the intestinal membrane permeability in mice was significantly increased with the phospholipid complexing technique (Ma et al., 2014).

It has been stated in the literature that mangiferin has antioxidant, antibacterial, antiviral, antitumor, immunomodulatory, and antidiabetic effects (Núñez Selles et al., 2016).

2.2.1. Antidiabetic Effects

Oxidative stress in diabetic tissues, which occurs as a result of the deterioration of the antioxidant defense system and accumulation of free radicals, can cause oxidative tissue damage in the tissues. The effect of mangiferin on antioxidant defense mechanism and cell damage in the pancreas in diabetic mice is examined, it was stated that mangiferin decreased blood glucose level, increased insulin level, and

modulated the oxidative stress biomarkers and non-enzymatic antioxidant status of the pancreas. It has been stated that mangiferin prevents oxidative stress due to its antioxidant properties and thus protects the pancreatic cell against damage (Sellamuthu et al., 2013). Mangiferin improved β-cell function, alleviated insulin resistance, decreased serum triglyceride, low-density lipoprotein cholesterol, liver triglyceride, and total cholesterol content, and increased liver glycogen storage content in diabetic insulin-resistant rats fed a high-fat and high-fructose diet. It is stated that the effects of mangiferin on diabetes may be due to its ability to restore the serum adipokine level, which causes a decrease in TNF-α, which acts as an oxidant, and adipokine level, which causes an increase in adiponectin, which has an antidiabetic effect and may have positive effects on insulin sensitivity (Saleh et al., 2014). Oxidative stress may be effective in the development of diabetes-induced nephropathy, which is an important complication of diabetes mellitus. It is thought that mangiferin may protect the kidneys from damage caused by diabetic nephropathy due to its antioxidant properties. It is stated that mangiferin shows its protective effect by reducing the ratio of kidneys to body weight, the plasma glucose level, blood urea nitrogen, uric acid, and creatine in the plasma and albumin in the urine (Pal et al., 2014).

2.2.2. Antioxidant Effect

It is stated that free radicals (ROS) can form in the human body during various metabolic processes. As a result of the excessive production of these free radicals or the suppression of the systems that help to

eliminate the excessively produced ROS in the cells, a significant increase in the amount of ROS occurs in the cell. Therefore, oxidative stress occurs in the cell, and at the same time, damage to DNA, lipids, proteins and cellular structure occurs. In cases where oxidative stress and the resulting ROS are persistent, cell death and various diseases may occur (Imran et al., 2017). Exposure of renal endothelial cells to cadmium may cause renal inflammation in humans. It has been stated that mangiferin inhibits the secretion of cadmium-induced interleukin-6 and interleukin-8, and mangiferin can be used as an antioxidant to prevent kidney inflammation due to cadmium exposure (Rajendran et al., 2015). In another study, it is stated that mangiferin has an antigenotoxic effect by eliminating free radicals against cadmium chloride ($CdCl_2$)-induced genotoxicity (Kasi et al., 2010). It has been observed that mangiferin herbosome slows down the formation of reactive oxygen species and significantly reduces the levels of total bilirubin, alanine aminotransferase, aspartate aminotransferase, and alkaline phosphatase (Jain et al., 2013). In a rat model investigating its neuroprotective effect against schizophrenia, mangiferin has a neuroprotective effect related to its anti-inflammatory and antioxidant protective mechanism (Rao et al., 2012).

2.2.3. Antitumor Effect

The anticancer, antitumor and apoptosis-inducing effects of mangiferin are thought to induce apoptosis by preventing the proliferation of cancer cells, which is one of the main mechanisms (Núñez Selles et al., 2016). When the effect of mangiferin on the thyroid cancer cell line in humans

was examined, it was stated that it inhibited thyroid cancer cell line proliferation significantly, mangiferin triggered apoptotic pathways and decreased the viability of the thyroid cancer cell line by suppressing proliferating cell nuclear antigens (Zhang & Wang, 2018). When the effect of mangiferin on prostate tumor cells in female rats was examined, it was observed that the tumor volumes of the animal group treated with mangiferin were reduced by more than five times compared to the control group (Al-Yasiri et al., 2017). It has been reported that mangiferin purified from plant sources has in vivo growth-inhibitory activity against ascitic fibrosarcoma in mice, with the increased killing of tumor cells in the spleen (Guha et al., 1996).

2.2.4. Antiviral and Antibacterial Effect

Mangiferin may have an antagonistic effect on the cytopathic effect of Human Immunodeficiency Virus (HIV) in vitro (Guha et al., 1996). In another study, it was observed that Mangiferin inhibited replication of Herpes simplex virus type 1 in vitro with its antiviral effect (Zheng & Lu, 1990). It was observed that mangiferin showed maximum inhibition for the Acyclovir-resistant AR-29 strain and alleviated the lesions, increasing the healing compared to the Acyclovir-susceptible Herpes Simplex type 1 (HSV-1) KOS strains (Rechenchoski et al., 2020). It has been reported that *Dimorphandra gardnerian* galactomannans and mangiferin inhibit herpes simplexvirus type 1 and poliovirus type 1 replication with high selectivity and low cytotoxicity (Rechenchoski et al., 2019). In vitro antibacterial activity of isolated mangiferin against *Salmonella typhi* and *Staphylococcus aureus* was confirmed (Biswas et

al., 2015). In mice treated with mangiferin, *Trichinella spiralis* has been shown to reduce serum levels of IgE by inhibiting mast cell degranulation throughout the parasite life cycle, and the number of *T. spiralis* larvae is reduced (García et al., 2003).

2.2.5. Immunomodulatory Effect

Mangiferin has an effect on the cell-mediated and humoral components of the immune system in mice, and it has been reported that delayed-type hypersensitivity and an increase in humoral antibody levels are detected. It is stated that the immunostimulating properties of mangiferin are important (Makare et al., 2001). It has been observed that mangiferin treatment promotes serum albumin, lysozyme, superoxide anion production, and serum bactericidal activity in rohu (*Labeo rohita*) carp infected with *Aeromonas hydrophila* and stimulates immune systems by increasing resistance to *Aeromonas hydrophila* infection (Sahu et al., 2007). When the effect of mangiferin on the immune system and cyclophosphamide-induced immunotoxicity in a rat model was examined, it was stated that decreased cellular responses, immunoglobulin M levels, and lymphoid organ weights increased after mangiferin administration. It has also been reported that mangiferin prevents tissue damage and immunotoxicity caused by cyclophosphamide. Mangiferin has an immunoprotective effect by inhibiting oxidative stress in macrophages, neutrophils, and lymphocytes (Muruganandan et al., 2005).

CONCLUSION

The products of the mango tree have commercial importance in terms of ornamental, medical and food. Mango fruit contains valuable nutrients and bioactive substances such as mangiferin. It is stated to that it has many beneficial health effects. Mangiferin has been reported to have various pharmacological effects in some studies. However, due to the limited number of these studies, more clinical studies are needed on mangiferin. At the same time, further studies are needed on its industrial use, as it has high antioxidant properties.

REFERENCES

Ajila, C.M., Naidu, K.A., Bhat, S.G., & Rao, U.P. (2007). Bioactive compounds and antioxidant potential of mango peel extract. Food chemistry, 105(3): 982-988.

Al-Yasiri, A.Y., Khoobchandani, M., Cutler, C.S., Watkinson, L., Carmack, T., Smith, C.J., & Katti, K.V. (2017). Mangiferin functionalized radioactive gold nanoparticles (MGF-198AuNPs) in prostate tumor therapy: green nanotechnology for production, in vivo tumor retention and evaluation of therapeutic efficacy. Dalton Transactions, 46(42): 14561-14571.

Bally, I.S.E. (2006). *Mangifera indica* (Mango). Species Profiles for Pacific Island Agroforestry, 1-25.

Biswas, T., Sen, A., Roy, R., Maji, S., & Maji, H.S. (2015). Isolation of mangiferin from flowering buds of *Mangifera indica* L. and its evaluation of in vitro antibacterial activity. Journal of Pharmaceutical Analysis, 4(3): 49–56.

Bokonon-Ganta, A.H., de Groote, H., & Neuenschwander, P. (2002). Socio-economic impact of biological control of mango mealybug in Benin. Agriculture, Ecosystems & Environment, 93(1-3): 367-378.

Daud, N.H., Aung, C.S., Hewavitharana, A.K., Wilkinson, A.S., Pierson, J.T., Roberts-Thomson, S.J., ... & Parat, M.O. (2010). Mango extracts and the mango component mangiferin promote endothelial cell migration. Journal of Agricultural and Food Chemistry, 58(8): 5181-5186.

García, D., Escalante, M., Delgado, R., Ubeira, F.M., & Leiro, J. (2003). Anthelminthic and antiallergic activities of *Mangifera indica* L. stem bark components vimang and mangiferin. Phytotherapy Research, 17(10): 1203-1208.

Guha, S., Ghosal, S. & Chattopadhyay, U. (1996). Antitumor, immunomodulatory and Anti-HIV effect of mangiferin, a naturally occurring glucosylxanthone. Chemotherapy, 42(6): 443-451.

Han, D., Chen, C., Zhang, C., Zhang, Y., & Tang, X. (2010). Determination of mangiferin in rat plasma by liquid–liquid extraction with UPLC–MS/MS. Journal of Pharmaceutical and Biomedical Analysis, 51(1): 260–263.

Imran, M., Arshad, M.S., Butt, M.S., Kwon, J.H., Arshad, M.U., & Sultan, M.T. (2017). Mangiferin: a natural miracle bioactive compound against lifestyle related disorders. Lipids in Health and Disease, 16(1): 1-17.

Jahurul, M.H.A., Zaidul, I.S.M., Ghafoor, K., Al-Juhaimi, F.Y., Nyam, K.L., Norulaini, N.A.N., ... & Omar, A.M. (2015). Mango (*Mangifera indica* L.) by-products and their valuable components: A review. Food chemistry, 183: 173-180.

Jain, P.K., Kharya, M., & Gajbhiye, A. (2013). Pharmacological evaluation of mangiferin herbosomes for antioxidant and hepatoprotection potential against ethanol induced hepatic damage. Drug Development and Industrial Pharmacy, 39(11): 1840–1850.

Kalra, B., Gupta, L., Khandelwal, D., & Choubey, N. (2018). Mango and diabetes. Journal of Social Health and Diabetes, 6(1): 56-58.

Kasbe, P., Jangra, A., & Lahkar, M. (2015). Mangiferin ameliorates aluminium chloride-induced cognitive dysfunction via alleviation of hippocampal oxido-nitrosative stress, proinflammatory cytokines and acetylcholinesterase level. Journal of Trace Elements in Medicine and Biology, 31: 107–112.

Kasi Viswanadh, E., Nageshwar Rao, B., & Satish Rao, B. (2010). Antigenotoxic effect of mangiferin and changes in antioxidant enzyme levels of Swiss albino mice treated with cadmium chloride. Human & Experimental Toxicology, 29(5): 409–418.

Khurana, R.K., Kaur, R., Lohan, S., Singh, K.K., & Singh, B. (2016). Mangiferin: a promising anticancer bioactive. Pharmaceutical Patent Analyst, 5(3): 169–181.

Kittiphoom, S. (2012). Utilization of mango seed. International Food Research Journal, 19(4): 1325-1335.

Ma, H., Chen, H., Sun, L., Tong, L., & Zhang, T. (2014). Improving permeability and oral absorption of mangiferin by phospholipid complexation. Fitoterapia, 93: 54–61.

Makare, N., Bodhankar, S. & Rangari, V. (2001). Immunomodulatory activity of alcoholic extract of *Mangifera indica* L. in mice. Journal of Ethnopharmacology, 78(2-3): 133-137.

Matkowski, A., Kuś, P., Góralska, E., & Woźniak, D. (2013). Mangiferin – a bioactive xanthonoid, not only from mango and not just antioxidant. Mini-Reviews in Medicinal Chemistry, 13(3): 439–55.

Muruganandan, S., Lal, J., & Gupta, P.K. (2005). Immunotherapeutic effects of mangiferin mediated by the inhibition of oxidative stress to activated lymphocytes, neutrophils and macrophages. Toxicology, 215(1–2): 57–68.

Núñez Selles, A.J., Daglia, M., & Rastrelli, L. (2016). The potential role of mangiferin in cancer treatment through its immunomodulatory, anti-angiogenic, apoptopic, and gene regulatory effects. BioFactors, 42(5): 475–491.

Pal, P.B., Sinha, K., & Sil, P.C. (2014). Mangiferin attenuates diabetic nephropathy by inhibiting oxidative stress mediated signaling cascade, TNFα related and mitochondrial dependent apoptotic pathways in streptozotocin-induced diabetic rats. PLoS ONE, 9(9): e107220.

Parvez, G.M. (2016). Pharmacological activities of mango (*Mangifera indica*): a review. Journal of Pharmacognosy and Phytochemistry, 5(3): 1.

Pino, J.A., Mesa, J., Muñoz, Y., Martí, M.P., & Marbot, R. (2005). Volatile components from mango (*Mangifera indica* L.) cultivars. Journal of Agricultural and Food Chemistry, 53(6): 2213-2223.

Rajendran, P., Rengarajan, T., Nishigaki, Y., Palaniswami, R., & Nishigaki, I. (2015). In vitro studies on mangiferin protection against cadmium-induced human renal endothelial damage and cell death via the MAP kinase and NF-κB pathways. Journal of Receptors and Signal Transduction, 36(1): 57–66.

Ramírez, F. & Davenport, T.L. (2010). Mango (*Mangifera indica* L.) flowering physiology. Scientia Horticulturae, 126(2): 65-72.

Rao, V.S., Carvalho, A.C., Trevisan, M.T.S., Andrade, G.M., Nobre, H.V., Moraes, M.O., & Santos, F.A. (2012). Mangiferin ameliorates 6-hydroxydopamineinduced cytotoxicity and oxidative stress in ketamine model of schizophrenia. Pharmacological Reports, 64(4): 848–856.

Rechenchoski, D.Z., Agostinho, K.F., Faccin-Galhardi, L.C., Lonni, A.A.S.G., da Silva, J.V.H., de Andrade, F.G., ... & Linhares, R.E.C. (2020). Mangiferin: A promising natural xanthone from *Mangifera indica* for the control of acyclovir–resistant herpes simplex virus 1 infection. Bioorganic & Medicinal Chemistry, 28(4): 115304.

Rechenchoski, D.Z., Samensari, N.L., Faccin-Galhardi, L.C., de Almeida, R.R., Cunha, A.P., Ricardo, N.M., ... & Linhares, R.E. (2019). The combination of *Dimorphandra gardneriana* galactomannan and mangiferin inhibits herpes simplex and poliovirus. Current Pharmaceutical Biotechnology, 20(3): 215-221.

Sahu, S., Das, B.K., Pradhan, J., Mohapatra, B.C., Mishra, B.K., & Sarangi, N. (2007). Effect of *Magnifera indica* kernel as a feed additive on immunity and resistance to *Aeromonas hydrophila* in *Labeo rohita* fingerlings. Fish & Shellfish Immunology, 23(1): 109–118.

Saleh, S., El-Maraghy, N., Reda, E., & Barakat, W. (2014). Modulation of diabetes and dyslipidemia in diabetic insulin-resistant rats by mangiferin: role of adiponectin and TNF-α. Anais Da Academia Brasileira de Ciências, 86(4): 1935–1948.

Sekar, M. (2015). Molecules of interest–mangiferin–a review. Annual Research & Review in Biology, 5(4): 307-320.

Sellamuthu, P.S., Arulselvan, P., Muniappan, B.P., Fakurazi, S., & Kandasamy, M. (2013). Mangiferin from *Salacia chinensis* prevents oxidative stress and protects pancreatic β-Cells in streptozotocin-induced diabetic rats. Journal of Medicinal Food, 16(8): 719–727.

Shah, K., Patel, M., Patel, R., & Parmar, P. (2010). *Mangifera indica* (Mango). Pharmacognosy Reviews, 4(7): 42–48.

Singh, Z., Singh, R.K., Sane, V.A., & Nath, P. (2013). Mango-postharvest biology and biotechnology. Critical Reviews in Plant Sciences, 32(4): 217-236.

Swaroop, A., Bagchi, M., Moriyama, H., & Bagchi, D. (2018). Health benefits of mango (*Mangifera indica* L.) and mangiferin. Jpn J Med, 1(2): 149-154.

Tharanathan, R.N., Yashoda, H.M., & Prabha, T.N. (2006). Mango (*Mangifera indica* L.),"The king of fruits"-An overview. Food Reviews International, 22(2): 95-123.

Yang, S., Zhou, Q., Zhang, B., Zhang, L., Yang, D., Yang, H., ... & Lu, Y. (2020). Screening, characterization and evaluation of mangiferin polymorphs. Natural Products and Bioprospecting, 10(4): 187-200.

Zhang, L. & Wang, M. (2018). Growth inhibitory effect of mangiferin on thyroid cancer cell line TPC1. Biotechnology and Bioprocess Engineering, 23(6): 649-654.

Zheng, M.S. & Lu, Z.Y. (1990). Antiviral effect of mangiferin and isomangiferin on Herpex simplex virus. China Medicine Journal, 103: 160-165.

CHAPTER IV

GENERAL INFORMATION ABOUT SOME GRAPE VARIETIES IMPROVED AND GROWN IN TURKEY

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INTRODUCTION

Grape is one of the most widely cultivated fruits around the world. Due to a highly favorable climate, Turkey, the homeland of grapevine, has a long history of viticulture. Therefore, our country has a very rich grapevine genetic potential. Although this rich historical diversity has decreased from time to time, our country still constitutes a very important part of the world's vine genetic resource. The fact that grapevine has a great genetic potential in Anatolia shows that viticulture first started in this region and spread from here.

Indeed, it has been proven with documents and materials obtained from archaeological excavations that viticulture in Anatolia has a history of thousands of years. This richness started to be revealed with a national project called "Grapevine Genetic Resources", which was planned in the 1960s, and today, almost all of the grapevine genetic resources of our country have been recorded. A collection of more than 1400 local grape varieties grown in the country was completedvia the work of the “Tekirdağ Viticulture Research Institute” and the "National Collection Vineyard" was created. In addition, an analogous vineyard has been established in the "Manisa Viticulture Research Institute".

In the text, besides the grape varieties that are currently grown, foreign and indigenous varieties obtained through breeding are also discussed (Figure 1).

1. GENERAL INFORMATION ABOUT SOME GRAPE VARIETIES IMPROVED AND GROWN IN TURKEY

1.1. Grape Cultivars

Tekirdağ çekirdeksizi	
Berry shape	Round
Berry color	Dark red-purple
Berry size	Very large
Cluster shape	Winged conical
Cluster size	Very large
Time of ripening	Mid season
Pruning level	Mixed/Spur
Growth vigor	Medium
It is a hybrid of Alphonse lavallée x Sultani seedless, a thin-skinned and seedless table grape variety.	

Barış	
Berry shape	Round
Berry color	White
Berry size	Very large
Cluster shape	Winged conical
Cluster size	Very large
Time of ripening	Mid season
Pruning level	Mixed/Spur
Growth vigor	Vigorous
It is a hybrid of Cardinal x Beauty seedless, a thin-skinned and seedless table grape variety.	

Trakya ilkeren	
Berry shape	Round
Berry color	Blue-black
Berry size	Very large
Cluster shape	Winged conical
Cluster size	Very large
Time of ripening	Very early
Pruning level	Mixed/Spur
Growth vigor	Vigorous
It is a hybrid of A. lavallée x Perlette, a table grape variety. The berry does not break and the clusters can remanin on the vine for a long time.	

Reçel üzümü	
Berry shape	Oval
Berry color	Red-black
Berry size	Large
Cluster shape	Cylindrical
Cluster size	Very large
Time of ripening	Midseason
Pruning level	Mixed/Spur
Growth vigor	Medium
It is a hybrid of El hamra x Perlette, a thin-skinned, fruitful and table grape variety.	

Güz üzümü	
Berry shape	Oval
Berry color	White
Berry size	Large
Cluster shape	Winged cylindrical
Cluster size	Very large
Time of ripening	Late
Pruning level	Spur
Growth vigor	Vigorous
It is a hybrid of Emperor x Sultani seedless, a seedless table variety that is resistant to shipping and storage.	

Tekirdağ misketi	
Berry shape	Oval
Berry color	White
Berry size	Medium
Cluster shape	Winged conical
Cluster size	Large
Time of ripening	Early
Pruning level	Mixed
Growth vigor	Medium
It is a hybrid of Alexandria Muscat x Sultani seedless, a seedless table grape variety with muscat odor.	

Gönülçelen	
Berry shape	Roundish
Berry color	Dark red-purple
Berry size	Large
Cluster shape	Winged conical
Cluster size	Large
Time of ripening	Late
Pruning level	Mixed/Spur
Growth vigor	Medium
It is a hybrid of Italyx Reçel üzümü, a fruitful, crispy berried and table grape variety with muscat odor.	

Bozbey	
Berry shape	Oblong
Berry color	White
Berry size	Very large
Cluster shape	Winged conical
Cluster size	Very large
Time of ripening	Midseason
Pruning level	Mixed
Growth vigor	Vigorous
It is a hybrid of QueenxBeauty seedless, a wellfilled clustered and fruitful table grape variety.	

Güzgülü	
Berry shape	Round
Berry color	Pink
Berry size	Very large
Cluster shape	Winged conical
Cluster size	Large
Time of ripening	Late
Pruning level	Mixed
Growth vigor	Medium
It isa hybrid of Kırmızı şam x Barış, loose clustered, seedless, resistant to shipping and storage and a table grape variety.	

Süleymanpaşa beyazı	
Berry shape	Round
Berry color	White
Berry size	Medium
Cluster shape	Winged conical
Cluster size	Large
Time of ripening	Late
Pruning level	Mixed
Growth vigor	Vigorous
It is a hybrid of the Amasya beyazı x (16*A*101), a seedless, fruitful, table grape variety with crispy flesh and henna on the sun exposed side.	

Cengizbey	
Berry shape	Oblate oval
Berry color	Red-grey
Berry size	Large
Cluster shape	Winged conical
Cluster size	Large
Time of ripening	Mid season
Pruning level	Mixed
Growth vigor	Medium
It is a hybrid of Ribol x Güz üzümü, a fruitful, seedless table and dried grape variety.	

Özer beyazı	
Berry shape	Oval
Berry color	White
Berry size	Large
Cluster shape	Conical
Cluster size	Medium
Time of ripening	Very late
Pruning level	Mixed/Spur
Growth vigor	Medium
It is a hybrid of Ribol x Güz üzümü, a crispy fleshy,suitable for shipping and storage, seedless table grape variety.	

Kebeli	
Berry shape	Long oval
Berry color	White
Berry size	Large
Cluster shape	Conical
Cluster size	Large
Time of ripening	Late
Pruning level	Mixed/Spur
Growth vigor	Medium
It is a hybrid of Ribol x Güz üzümü, a seedless table grape variety whose sun-exposed parts are browned.	

Gürnil	
Berry shape	Long oval
Berry color	Dark red-purple
Berry size	Large
Cluster shape	Winged conical
Cluster size	Large
Time of ripening	Late
Pruning level	Mixed/Spur
Growth vigor	Medium
It is a hybrid of Italy x Reçel üzümü, a female flowered, suitable for shipping and storage, table grape variety	

Özer karası	
Berry shape	Obovate
Berry color	Dark red-purple
Berry size	Medium
Cluster shape	Conical
Cluster size	Medium
Time of ripening	Late
Pruning level	Mixed
Growth vigor	Medium
It is a hybrid of Italy x Favli, a compact clustered, tolerant of powdery mildew and wine grape variety.	

Tekirdağ sultanı	
Berry shape	Round
Berry color	White
Berry size	Very large
Cluster shape	Conical
Cluster size	Very large
Time of ripening	Mid season
Pruning level	Mixed
Growth vigor	Vigorous
It is a hybrid of Italy x Superior seedless and it is a table grape variety with a muscatodor.	

Emirali	
Berry shape	Oblate round
Berry color	Blue-black
Berry size	Very large
Cluster shape	Winged conical
Cluster size	Very large
Time of ripening	Very late
Pruning level	Mixed
Growth vigor	Medium
It is hybrid of Çınar karası x Tekirdağ çekirdeksizi, a fruitful table grape variety.	

(Karauz, 2013; Özer et al., 2014; Ergönül & Özer, 2017; Anonymous, 2017; Ergönül et al., 2018; Ergönül et al., 2021; Anonymous, 2021a)

Pembe 77	
Berry shape	Oval
Berry color	Pink
Berry size	Very large
Time of ripening	Late
Growth vigor	Vigorous
It is a hybrid of Alphonse lavallée x M. Reine des vignes. It is suitable for waiting on vines, a thick skinned, resistant to shipping and storage, fruitful, table grape variety. It is suitable for Marmara and Central Anatolia Region.	

İsmetbey	
Berry shape	Long oval
Berry color	Black
Berry size	Very large
Time of ripening	Midseason
Growth vigor	Vigorous
It is a hybrid of Siyahgemre x Royal and its fruit flesh is a little hard, fruitful, table grape variety.	

Atak 77	
Berry shape	Oval
Berry color	White
Berry size	Large
Time of ripening	Late
Growth vigor	Medium
It is a hybrid of Beyaz çavuş x Hamburg misketi and is suitable for especially late harvest areas.It is a table grape variety that can stay on the vine for a long time ıts clusters, fertile, suitable for storage and recommended for places where there is a risk of late frost.	

Yalova incisi	
Berry shape	Oval
Berry color	White
Berry size	Very large
Time of ripening	Very early
Growth vigor	Vigorous
It is a hybrid of Hönüsü x Siyah gemre and is a table grape variety with thick skin, crispy flesh and medium compact clusters. Suitable for short and mixed pruning.	

Ata sarısı	
Berry shape	Oval
Berry color	White
Berry size	Very large
Time of ripening	Midseason
Growth vigor	Vigorous
It is a hybrid of Beyaz çavuş x Cardinal and is a table grape variety with a thick skin, crispy flesh and medium compact clusters. It is suitable for short pruning.	

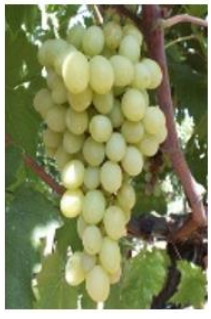
Yalova misketi	
Berry shape	Round
Berry color	Purplish black
Berry size	Large
Time of ripening	Early
Growth vigor	Vigorous
It is a hybrid of Royal x Perle de csaba and is a table grape variety with medium thick skin, crispy flesh, musk odor, medium compact bunches. Suitable for mixed/short pruning.	

Yalova beyazı	
Berry shape	Round
Berry color	White
Berry size	Very large
Time of ripening	Early
Growth vigor	Medium
It is a hybrid of Beyaz çavuş x Cardinal and is a table grape variety with medium thick skin, crispy flesh and medium compact clusters. Suitable for mixed/short pruning.	

Yalova çekirdeksizi	
Berry shape	Oval
Berry color	White
Berry size	Large
Time of ripening	Early
Growth vigor	Vigorous
It is a hybrid of Beyrut hurması x Perlette and is a table grape variety with a thin skin, crispy flesh and medium compact clusters. Suitable for long pruning.	

Ergin çekirdeksizi	
Berry shape	Round
Berry color	White
Berry size	Medium
Time of ripening	Early
Growth vigor	Vigorous
It is a hybrid of Beyrut hurması x Perlette and is a medium thickskinned, juicy table grape variety with compact clusters. It is suitable for mixed pruning.	

Samancı çekirdeksizi	
Berry shape	Oval
Berry color	White
Berry size	Very large
Time of ripening	Early
Growth vigor	Vigorous
It is a hybrid of Beyaz şam x Perlette and is a thin skinned, crispy fleshed, loose bunched table and dried grape variety. Suitable for long pruning.	



Arif bey	
Berry shape	Oval
Berry color	White
Berry size	Very large
Time of ripening	Midseason
Growth vigor	Medium
It is a hybrid of Beyaz şam x Müşküle and is a table grape variety with medium thick skin, crispy flesh and medium compact clusters. It is tolerant to fungal diseases and suitable for storage.	

Uslu	
Berry shape	Long oval
Berry color	Dark red
Berry size	Very large
Time of ripening	Very early
Growth vigor	Vigorous
It is a hybrid of Hönüsü x Siyah gemre and is a table grape variety with thin skin, crispy flesh and loose clusters. Suitable for short and mixed pruning.	

(Özer et al., 2014; Anonymous, 2017; Ergönül et al., 2021; Anonymous, 2021b)

Karaerik	
Berry shape	Oval
Berry color	Purplish black
Berry size	Large
Berry skin thickness	Medium
Cluster shape	Winged conical
Cluster size	Medium
Cluster compactness	Medium
Time of ripening	Midseason
Pruning level	Spur
It is a table grape variety widely grown in Erzincan.	

Spil karası	
Berry shape	Oval
Berry color	Blue black
Berry size	Medium
Berry skin thickness	Medium
Cluster shape	Winged conical
Cluster size	Medium
Cluster compactness	Loose
Time of ripening	Early
Pruning level	Spur/Mixed
It is a hybrid of Mahrabaşı x Trakya İlkeren and is a table grape variety.	

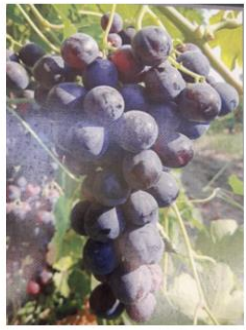
Manisa Pembesi	
Berry shape	Oval
Berry color	Dark red-violet
Berry size	Very large
Berry skin thickness	Medium
Cluster shape	Winged conical
Cluster size	Medium
Cluster compactness	Medium
Time of ripening	Early
Pruning level	Spur/Mixed
It is a hybrid of Mahrabaşı x Cardinal and is a table grape variety.	

Lidya	
Berry shape	Oval
Berry color	Dark red-violet
Berry size	Very large
Berry skin thickness	Medium
Cluster shape	Conical
Cluster size	Very large
Cluster compactness	Medium
Time of ripening	Midseason
Pruning level	Spur/Mixed
It is a hybrid of Tahannebi x Cardinal and is a table grape variety.	

Beyra	
Berry shape	Large oval
Berry color	Dark red-violet
Berry size	Very large
Berry skin thickness	Medium
Cluster shape	Conical
Cluster size	Very large
Cluster compactness	Medium
Time of ripening	Midseason
Pruning level	Spur/Mixed
It is a hybrid of Mahrabaşı x Cardinal and is a table grape variety.	

Mesir	
Berry shape	Large oval
Berry color	Dark red-violet
Berry size	Very large
Berry skin thickness	Medium
Cluster shape	Winged conical
Cluster size	Large
Cluster compactness	Loose
Time of ripening	Midseason
Pruning level	Spur/Mixed
It is a hybrid of Mahrabaşı x Hamburg misketi and is a table grape variety.	

Efem	
Berry shape	Round
Berry color	Blue black
Berry size	Very large
Berry skin thickness	Medium
Cluster shape	Conical
Cluster size	Medium
Salkım Compactness	Medium
Time of ripening	Midseason
Pruning level	Spur/Mixed
It is a hybrid of Mahrabaşı x Hamburg and is a table grape variety.	



Ece	
Berry shape	Oval
Berry color	Blue black
Berry size	Very large
Berry skin thickness	Medium
Cluster shape	Winged conical
Cluster size	Large
Cluster compactness	Loose
Time of ripening	Early
Pruning level	Spur/Mixed
It is a hybrid of Mahrabaşı x Cardinal and is a table grape variety.	

(Dilli & Baybaş, 2018; Atak & Sağlam, 2021; Ergönül et al., 2021; Anonymous, 2021c)

Çeliksu	
Berry shape	Round
Berry color	Black
Berry size	Medium
Berry skin thickness	Very thick
Cluster shape	Winged Conical, Conical
Cluster size	Very small
Cluster compactness	Compact
Time of ripening	Midseason
Pruning level	Long/Mixed
It is fruitful, the fruit flesh is colorless and juicy, the berry stalk is spur, foxy flavor, the dry matter is low, the seed is very large.	

Rizellim	
Berry shape	Round
Berry color	Black
Berry size	Medium
Berry skin thickness	Very thick
Cluster shape	Winged conical, Conical
Cluster size	Small
Cluster compactness	Compact
Time of ripening	Midseason
Pruning level	Long/Mixed
It is fruitful, the flesh is colorless and juicy, the berry stalk is short, it has a foxy flavor, the dry matter is medium, the seed is large.	

Ülkemiz	
Berry shape	Round
Berry color	Dark red-purple
Berry size	Medium
Berry skin thickness	Thick
Cluster shape	Conical
Cluster size	Small
Cluster compactness	Compact
Time of ripening	Midseason
Pruning level	Long/Mixed
It is fruitful, the flesh is colorless and juicy, the berry stalk is very short, it has a foxy flavor, the dry matter is low, the seed is large.	

Rizessi	
Berry shape	Round
Berry color	Black
Berry size	Medium
Berry skin thickness	Very thick
Cluster shape	Conical
Cluster size	Small
Cluster compactness	Compact
Time of ripening	Midseason
Pruning level	Long/Mixed
It is fruitful, the flesh is colorless and juicy, the berry stalk is short, it has a foxy flavor, the dry matter is medium, the seed is large.	

Rizpem	
Berry shape	Round
Berry color	Red pink
Berry size	Medium
Berry skin thickness	Thick
Cluster shape	Conical
Cluster size	Small
Cluster compactness	Medium
Time of ripening	Midseason
Pruning level	Long/Mixed
It is fruitful, the flesh is colorless and juicy, the berry stalk is very short, it has a foxy flavor, dry matter is high, the seed is large.	

(Çelik et al., 2018)

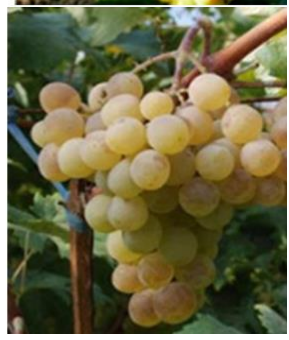
Mevlana	
Berry shape	Long oval
Berry color	White
Berry size	Large
Berry skin thickness	Medium
Cluster shape	Cylindrical
Cluster size	Large
Cluster compactness	Loose
Time of ripening	Midseason
Pruning level	Long/Semi Long
Fruit flesh is a juicy and fruitful table grape variety. When it is kept covered for a longer time, it can find buyers at high prices.	

Emir	
Berry shape	Round
Berry color	White
Berry size	Medium
Berry skin thickness	Medium
Cluster shape	Conical
Cluster size	Medium
Cluster compactness	Compact
Time of ripening	Midseason
Pruning level	Spur
It is a table and must grape variety.	

Bozcaada çavuşu	
Berry shape	Oval
Berry color	White
Berry size	Large
Berry skin thickness	Thin
Cluster shape	Conical
Cluster size	Large
Cluster compactness	Loose
Time of ripening	Midseason
Pruning level	Spur
It is a sterile and table grape variety. Therefore, Karasakız, Hacıbalbal and Hamburg misketi are used as pollinators.	

Hafızali	
Berry shape	Long oval
Berry color	White
Berry size	Large
Berry skin thickness	Medium
Cluster shape	Winged conical
Cluster size	Large
Cluster compactness	Medium
Time of ripening	Midseason
Pruning level	Spur/Mixed
It is a table grape variety and its growing is strong and fruitful.	

Müşküle	
Berry shape	Oval
Berry color	White
Berry size	Medium
Berry skin thickness	Thick
Cluster shape	Wingedconical
Cluster size	Medium
Cluster compactness	Medium
Time of ripening	Late
Pruning level	Spur/Mixed
It is a table grape variety with good resistance to cold storage and shipping.	



Razaki	
Berry shape	Long oval
Berry color	White
Berry size	Large
Berry skin thickness	Thin
Cluster shape	Wingedconical
Cluster size	Large
Cluster compactness	Medium
Time of ripening	Midseason
Pruning level	Mixed
It is a table grape variety, fruitful, shipping and storage resistant.	

Tarsus beyazı	
Berry shape	Round
Berry color	White
Berry size	Large
Berry skin thickness	Thick
Cluster shape	Winged conical
Cluster size	Large
Cluster compactness	Medium
Time of ripening	Early
Pruning level	Spur
It is a table grape variety with berry shattered feature. Plant growing is strong and fruitful.	

Tahannebi	
Berry shape	Long oval
Berry color	White
Berry size	Large
Berry skin thickness	Thin
Cluster shape	Wingedconical
Cluster size	Medium
Cluster compactness	Medium
Time of ripening	Late
Pruning level	Mixed
It is a table grape variety. However, Kabarcık and Sergi karası are used as pollinators because it is sterile.	

Cardinal	
Berry shape	Oval
Berry color	Red
Berry size	Large
Berry skin thickness	Medium
Cluster shape	Conical cylindrical
Cluster size	Large
Cluster compactness	Loose
Time of ripening	Early
Pruning level	Spur
It can cause sunburn in hot areas, and berry cracking in the bottom lands. It is a table variety.	

Narince	
Berry shape	Round
Berry color	White
Berry size	Medium
Berry skin thickness	Medium
Cluster shape	Winged conical
Cluster size	Large
Cluster compactness	Wellfilled
Time of ripening	Midseason
Pruning level	Spur/Mixed
It is a kind of wine, must and table grape variety, and its leaves are very suitable for making brine.	

Yuvarlak çekirdeksiz	
Berry shape	Round
Berry color	White
Berry size	Small
Berry skin thickness	Thin
Cluster shape	Long Cylindrical
Cluster size	Large
Cluster compactness	Compact
Time of ripening	Midseason
Pruning level	Long
It is a seedless variety for drying and table grape, and it canshatter berry when it waits.	

Yapıncak	
Berry shape	Oval
Berry color	White
Berry size	Medium
Berry skin thickness	Medium
Cluster shape	Long conical
Cluster size	Medium
Cluster compactness	Medium
Time of ripening	Midseason
Pruning level	Spur
It is used for all purposes and its leaves are very suitable for making brine.	

Kalecik karası	
Berry shape	Round
Berry color	Black
Berry size	Small
Berry skin thickness	Thick
Cluster shape	Winged conical
Cluster size	Small
Cluster compactness	Compact
Time of ripening	Midseason
Pruning level	Spur
It is a fruitful, table and must grape variety.	

Boğazkere	
Berry shape	Round
Berry color	Black
Berry size	Medium
Berry skin thickness	Medium
Cluster shape	Winged conical
Cluster size	Medium
Cluster compactness	Compact
Time of ripening	Midseason
Pruning level	Mixed
It is a fruitful, table and must grape variety.	

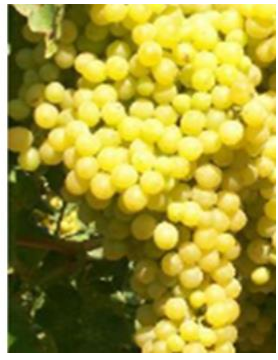
Öküzgözü	
Berry shape	Oval
Berry color	Black
Berry size	Large
Berry skin thickness	Medium
Cluster shape	Winged conical
Cluster size	Large
Cluster compactness	Compact
Time of ripening	Late
Pruning level	Spur/Mixed
It can be used as a table grape, although it is a kind of wine grape.	

Sergi karası	
Berry shape	Oval
Berry color	Black
Berry size	Large
Berry skin thickness	Medium
Cluster shape	Conical
Cluster size	Large
Cluster compactness	Compact
Time of ripening	Midseason
Pruning level	Mixed
It is used for drying, grape juice, wine and table grape.	

Hönüsü (Mahrabaşı)	
Berry shape	Long oval
Berry color	Red mor
Berry size	Large
Berry skin thickness	Thin
Cluster shape	Winged conical
Cluster size	Large
Cluster compactness	Medium
Time of ripening	Late
Pruning level	Semi long
Since the flower structure of the table variety is female, it is necessary to use a pollinator variety. For this, Dökülgen is used. It is resistant to shipping.	

Hamburg misketi	
Berry shape	Round
Berry color	Black
Berry size	Medium
Berry skin thickness	Medium
Cluster shape	Winged conical
Cluster size	Medium
Cluster compactness	Medium
Time of ripening	Midseason
Pruning level	Semi long
It is anodorous variety evaluated as table, wine/must grape variety. It is a good and fruitful variety.	

Sultani çekirdeksiz	
Berry shape	Oval
Berry color	White
Berry size	Small
Berry skin thickness	Thick
Cluster shape	Winged cylindrical
Cluster size	Large
Cluster compactness	Compact
Time of ripening	Midseason
Pruning level	Long
Although it is used for drying, it is also considered as table food and can shatter berry. Its vine grows strong.	



Alphonse lavalleé	
Berry shape	Round
Berry color	Black mor
Berry size	Large
Berry skin thickness	Thick
Cluster shape	Winged conical
Cluster size	Large
Cluster compactness	Medium
Time of ripening	Late
Pruning level	Spur
It is a table grape variety that is resistant to shipping and storage.	

İzabella (Çilek üzümü)	
Berry shape	Round
Berry color	Black
Berry size	Medium
Berry skin thickness	Thick
Cluster shape	Conical
Cluster size	Small
Cluster compactness	Compact
Time of ripening	Late
Pruning level	Spur/Mixed
It is a hybrid of *V. labrusca*. Strawberry-scented, resistant to fungal diseases, table / must grape variety.	

İtalya	
Berry shape	Long oval
Berry color	White
Berry size	Large
Berry skin thickness	Medium
Cluster shape	Conical
Cluster size	Large
Cluster compactness	Medium
Time of ripening	Midseason
Pruning level	Spur
It is a table grape variety with a musk smell and sensitive to fungal diseases. Plant growing and yield are good.	

Red Globe	
Berry shape	Round
Berry color	Red
Berry size	Large
Berry skin thickness	Medium
Cluster shape	Conical
Cluster size	Medium
Cluster compactness	Medium
Time of ripening	Late
Pruning level	Spur
It is a table grape variety.It is very fruitful,.especially in the pergola system.	

Michele palieri	
Berry shape	Oval
Berry color	Purple black
Berry size	Large
Berry skin thickness	Medium
Cluster shape	Conical
Cluster size	Large
Cluster compactness	Compact
Time of ripening	Midseason
Pruning level	Semi long
It is a hybrid of A. Lavallée x Red malaga and is a wine grape variety.	

Cabarnet sauvignon	
Berry shape	Round
Berry color	Black
Berry size	Small
Berry skin thickness	Thick
Cluster shape	Long conical
Cluster size	Small
Cluster compactness	Compact
Time of ripening	Midseason
Pruning level	Spur/Semi long
The variety used as a wine grape adapts better to cooler regions.	

Syrah (Şiraz)	
Berry shape	Oval
Berry color	Blue black
Berry size	Small
Berry skin thickness	Medium
Cluster shape	Winged cylindrical
Cluster size	Medium
Cluster compactness	Compact
Time of ripening	Midseason
Pruning level	Spur
The variety used as a wine grape is very sensitive to drought and grey mold *(Botrytis cinerea)*.	

Merlot	
Berry shape	Round
Berry color	Blue black
Berry size	Small
Berry skin thickness	Medium
Cluster shape	Winged conical
Cluster size	Small
Cluster compactness	Compact
Time of ripening	Midseason
Pruning level	Spur/Semi long
It is used as a wine/must grape. Since their buds break early, they can be damaged by late frosts.	

Alicante bouschet	
Berry shape	Round
Berry color	Purplish black
Berry size	Medium
Berry skin thickness	Medium
Cluster shape	Winged conical
Cluster size	Medium
Cluster compactness	Compact
Time of ripening	Midseason
Pruning level	Spur
This variety, whose flesh is also colored, is used as a wine grape.	

Kabarcık	
Berry shape	Round
Berry color	White
Berry size	Medium
Berry skin thickness	Thin
Cluster shape	Conical
Cluster size	Medium
Cluster compactness	Compact
Time of ripening	Mid season
Pruning level	Spur/ Semi long
The variety, which is used as a must/wine and table grape, is fruitful and has strong vines.	

(Anonymous, 1990; Çelik, 2002; Çelik et al., 1998; Anonymous, 2017; Atak & Sağlam, 2021; Ergönül et al., 2021)

Figure 1: Grape Cultivars and Their Some Features

CONCLUSION

Anatolia, which lies between 36°- 42° north latitudes, has a wide variety of grapes thanks to a number of factors such as having a suitable location for viticulture, being surrounded by water on three sides and having hosted numerous civilizations over millenia. This situation also provided the opportunity to utilize grapes in many different ways. Despite this richness of varieties, the great change in consumer preferences has led experts to obtain new varieties with different characteristics by using different breeding methods.

REFERENCES

Anonymous, (1990). Standard Grape Varieties Catalogue. Republic Of Turkey, Ministry of Agriculture, Forestry and Rural Affairs, Ankara.

Anonymous, (2017). Producer's Guide-Grapes. Model Development for Agricultural Rural Development in Disadvantaged Rural Areas and Value Chain Analysis Research and Study Project in Apple, Cherry, Grape and Strawberry Fruits. Global Consulting and Training Services.

Anonymous, (2021a). https://arastirma.tarimorman.gov.tr/bagcilik/Menu/17/Cesitler-_-Urunler (Access date: 29.10.2021)

Anonymous, (2021b). https://arastirma.tarimorman.gov.tr/yalovabahce /Menu/34/ Meyveler (Access date: 29.10.2021)

Anonymous, (2021c). https://arastirma.tarimorman.gov.tr/manisabagcilik /Lists/ Sol Menu/Attachments/43/yeni%20%c3%a7e%c5%9fitler.pdf (Access date: 29.10.2021)

Atak, A. & Sağlam, H. (2021). Grape varieties cultivated in our country (viticulture/grape growing). Tarim Gündem Magazine, Special Issue: p.59-67.

Çelik, H. (2002). Grape Varieties Catalogue. Sun Fidan Incorporated Company. Professional Books Series: 2, Ankara.

Çelik, H., Ağaoğlu, Y.S., Fidan, Y., Marasalı, B., & Söylemezoğlu, G. (1998). General Viticulture. Sun Fidan Incorporated Company. Professional Books Series:1, Ankara. pp: 253p.

Çelik, H., Köse, B., & Ateş, S. (2018). New Fragrant Grape (*V. labrusca* L.) varieties selected and registered from the black sea region. Bahçe 47 (Special Issue 1), Turkey 9th Viticulture and Technologies Symposium. pp: 299-309.

Dilli, Y. & Baybaş, B. (2018). Registered Grape Varieties Catalogue. Republic Of Turkey, Ministry of Agriculture, Forestry and Rural Affairs, General Directorate Of Agricultural Research and Policies, Research & Development Innovation, Manisa Viticulture Research Enstitute Directorate.

Ergönül, O. & Özer, C. (2017): Newly Developed Grape Varieties and Their Uses.

Ergönül, O., Özer, C., & Özalp, O.Z. (2018). New table grape varieties developed by Tekirdağ Viticulture Research Institute. Bahçe 47 (Special Issue), Turkey 9th Viticulture and Technologies Symposium) pp: 423–428.

Ergönül, O., Uysal, T., & Polat, A. (2021). What Are the Characteristics of Grape Varieties? (Practical Viticulture). Tekirdağ Viticulture Research Institute, Tekirdağ, pp: 87-109.

Karauz, A. (2013). Parental Analysis of Some Grape Varieties Obtained by Crossbreeding and Marker Based Selection of Seedless Individuals. PhD Thesis. Namık Kemal University. Graduate School of Natural and Applied Sciences. Department of Horticulture, Tekirdağ.

Özer, C., Boz, Y., & Atak, A. (2014). Our grape breeding studies by crossbreeding. Turkey Seed Growers Union Magazine, Year: 3, Number: 11, Ankara, pp: 11-17. Union Of Chambers Of Agriculture Of Turkey, Farmer and Village World, Number: 303, pp: 51-55.

CHAPTER V

PLANT PARASITIC NEMATODES IN ORCHARDS AND THEIR MANAGEMENT OPPORTUNITIES

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INTRODUCTION

Agricultural areas all over the world are gradually decreasing, and for this reason, adequate and balanced nutrition problems have emerged for the world population. In order to solve the problem of balanced nutrition, fruit and vegetable production and consumption should be expanded (Akbay et al., 2005). The main countries in world fruit production are China, India, Brazil, USA, Italy, Spain, Mexico, Indonesia, Iran, Philippines, France, Turkey. Today, China is the leader in world fruit production.

Although the geographical shape, soil structure and ecological conditions of many agricultural areas are suitable for fruit growing in the world, significant product losses are observed due to some diseases, pests and nematodes. They were caused economic damage and yileld losses. Fruit producers were aimed obtain high quality and healthy fruits while establishing their gardens. Each fruit variety has prefers different conditions to grow. Therefore, locations should be chosen carefully when establishing gardens. Factors, such as climatic conditions, direction of sunlight, soil conditions and pest risk play an important role in the selection of the location and the plant preferred in that location. Some spider mites, insects, other arthropods and nematodes feed on and damage fruit trees. In addition to their direct damage, they can also become a problem in the gardens by indirectly carrying some diseases (Crow & Rich, 2009).

1. CLASSIFICATION OF PLANT PARASITIC NEMATODES IN FRUIT GARDENS

Different species of plant parasitic nematodes were grouped into three groups according to their biology.

1.1. Endoparasitic Nematodes

These nematodes are finalize their growth in plant tissues and usually lay eggs in the tissue. In addition to they living in the roots of most plants, sometimes live and feed in the stems, stems, leaves, flowers and seeds of plants. Some nematodes carry important plant viruses to the tissues where they feed.

1.2.Semi-Endoparasitic Nematodes

This group nematodes are feed and survive by inserting their heads into the roots and rootlets of plants. Since their bodies are outside the root, they lay their eggs outside. They use plant nutrients, disrupt the mineral and water cycle in the plant. Therefore, they allow other pests and pathogens to damage the plant.

1.3.Ectoparasitic Nematodes

The nematodes in this group feed and continue their lives by inserting their stylets without inserting their heads into the roots of the plants. Since their bodies are outside the root, they lay their eggs outside. The nematodes collected in three groups are further divided into two subgroups each.

2.3.1.Persistent Nematodes

These are nematodes that fix themselves on the host plant at any stage of their growth and do not move.

2.3.2.Migratory Nematodes

These are nematodes that leave the host during the larval or adult stage and migrate (Pehlivan, 1995).

Different types of nematodes causing damage to various fruit trees have been identified and reported. But some of them cause economic damage to trees.

1- *Meloidogyne* spp. (Root-knot nematodes)
2- *Pratylenchus* spp. (Root lesion nematodes)
3- *Criconemella* spp. (Ring nematodes)
4- *Xiphinema* spp. (Dagger nematodes)
5- *Belonolaimus* spp. (Sting nematodes)
6 - *Tylenchulus* spp. (Citrus nematodes)
7- *Helicotylenchus* spp. (Spiral nematodes)
8- *Aphelenchoides* spp. (Strawberry leaf nematodes)
9- *Hetoredera* spp. (Cyst nematodes)

1- *Meloidogyne* spp. (Root-knot nematodes)

The second stages and males of root-knot nematodes (*Meloidogyne* spp.) are wormlike, females are pear -shaped microscopic creatures. They are easily recognized by forming large and small knots on the host roots. Females 0.7–0.8 mm long by 0.4–0.5 mm wide; males are 1.2–

2.0 mm long and larvae are 0.3–0.5 mm long. The female dies after laying her eggs in a gelatinous substance that is partly embedded in the root behind her body and partly on the root surface. If the soil temperature is below 10°C, it cannot grow, and the damage starts at 15 °C. Growth time is 3-4 weeks at 27 °C under laboratory conditions.

Infective larvae feed on the root and they produce galls or galls in the root. These galls vary in size from 3-12 mm and prevent uptake of water and plant nutrients. They disrupt the normal function of the roots and cause fungal and bacterial agents that cause disease in trees to enter the root more easily. Growth retardation and yellowing occur especially in young plants. It has serious damages in many fruit production areas in the world. Among the most important hosts in fruit areas are perennial fruits such as banana, peach, plum and mulberry (Whitehead, 1998). There are over 90 species of root-knot nematodes in the world, and seven species have been identified in our country.

2- *Pratylenchus* spp. (Root-lesion nematode)

Their body lengths are 0.3-0.9 mm. Root-lesion nematodes live in plant roots as endoparasites. It has been reported to have more than 300 hosts in the world. They feed by absorbing the sap in the parenchyma tissues of the plant and increase the susceptibility of plants against other soil-borne pathogens. They cause darkening of the roots, necrosis or death of the roots. It has been reported that lesion nematodes play a role in the emergence of "replant diseases", which is frequently seen in fruit growing areas (Utkhede et al., 1992; Dullahide et al., 1994). Damage to

fruits by root lesion nematodes varies depending on soil structure, population density, climate, and interactions with other pathogenic organisms (Dickerson et al., 2000).

3- *Mesocriconema* spp. (Ring nematodes)

Female individuals of this genus are 0.4-0.7 mm long. Male individuals are 0.5-0.6 mm long. They belong to the group of ectoparasitic nematodes. They feed on plant roots, especially using their long stylets. Like root lesion nematodes, they cause necrosis and blackening. They also prevent growth as they feed on the root tips. Although the damage is low in most fruit trees, serious weakening of the tree is observed (Bird and Melakeberhan 1993).

4- *Xiphinema* spp. (Dagger nematodes)

Dagger nematodes (*Xiphinema* spp.) are very long (up to 6 mm) nematodes with male and female wormlike. Their stylets up to 2 mm long in the head region.

They belong to the group of ectoparasitic nematodes. Dagger nematodes generally prefer medium to light soils with a pH of 6.5–7.5. The optimum temperature for their growth is 16–28 °C. They do not settle in the root, but they insert their long stylets into the deepest parts of the roots and feed. Wedge nematodes cause necrosis in roots, swelling and inhibition of development. In addition, dagger nematodes are vectors for most important viruses. *X. index* Cobb, which is the vector of vine fan leaf virus in vineyard areas, is distinguished with

other *Xiphinema* species by the presence of a very prominent finger-shaped protrusion at the end of the tail. It carries virus types such as *Xiphinema americanum* Cobb, tomato ringspot virus, tabacco ringspot virus, peach rosette mosaic virus. It carries *Xiphinema* index grapevine fanleaf virus. In addition, in the absence of this nematode virus, it causes significant damage to the vineyard areas as a result of feeding on the roots (Bird & Melakeberhan, 1993).

5- *Tylenchulus* spp. (*Citrus* nematodes)

It is 0.3-0.4 mm in length, and its males and undeveloped females are wormlike. The female citrus nematode fixes itself to the root and feeds here until it dies. After getting enough nourishment in the roots, their bodies begin to swell and take the form of a bag. second instar larvae feed by infecting the root. A female can lay 70–100 eggs in a gelatinous substance. They are persistent endoparasitic nematodes. It is common in fruit growing areas and creates a population density above the economic damage threshold, especially in summer. Plant development slows down and stops, stunting, yellowing of leaves, flower and fruit shedding occurs. If the infection is severe, the plant may dry out completely (Duncan & Eissenstat, 1993).

6- *Helicotylenchus* spp. (Spiral nematodes)

It is 0.5 mm in length and is a type of nematode with a C-shaped or spiral-shaped body. Stylet is well developed. They extend the head and front parts of the body generally parallel to the root, and the other part is in a curved state. *H. multicinctus* (Cobb), one of the spiral nematodes,

is an internal parasite only in bananas, although it is an external parasite on other plants. Characteristic macroscopic brown spots appear on plant roots damaged by the nematode. Damage to the roots prevents the development of the plant; shrinks in size; causes softening of the stem and yellowing of the leaves; The expected product cannot be obtained because the bunches of bananas are not sufficiently developed (Mcsorley & Parrado, 1983). Due to the rotting of the roots, if the banana cluster has formed and is in the ripening period, wind and heavy rains overthrow the plant (Tzortzakakis, 2008).

7- *Aphelenchoides* spp. (Strawberry leaf nematodes)

The male and female of the strawberry nematode (*Aphelencoides fragariae* Ritzema Bos) are wormlike microscopic creatures. They are approximately 0.5–1.0 mm in length. They live as external parasites (ectoparasites) in buds and plant growth point. It is possible to see the adults, larvae and eggs of the nematode together in the leaves surrounding the leaf bud of the plant. Humidity and temperature play an important role in their reproduction and in humid conditions, thousands of nematodes are found in the infected plant. It gives offspring every 10-11 days at 18 °C. Along with *A. fragariae, A.besseyi* and *A. ritzemabosi*, which are leaf nematodes, live as external parasites (ectoparasites) in strawberry buds, leaflets and petioles at the growth tips, and as internal parasites (endoparasite) in leaf tissue. The pest has a wide host range including various plants (strawberries, cut flowers, etc.) (Siddiqi, 1975). It has been reported that the symptoms of strawberry nematode are seen in early spring and cause wrinkling,

curling, discoloration of the leaves, and formation of small, light-colored fruits. In addition, as a result of the damage, there is a decrease in flowers and fruits (Dicker, 1948).

8- *Hetoredera fici* (Fig cyst nematodes)

The female of the fig cyst nematode (*Heterodera fici*) is pear or lemon shaped. The average length of the female is 1.4 mm. The male is in the form of wormlike. Females live on the roots of host plants by sucking the sap, but do not produce galls on the roots like Root-knot nematodes. The females are on the capillary roots with their head in the plant tissue and the body part hanging on the root. When they die, the outside of their body thickens and becomes a dark brown cyst that protects the eggs. The nematodes that feed on the thin roots of the fig tree damage the roots after a while (Anonymous, 2008).

2. DAMAGE OF HARMFUL NEMATODE SPECIES IN FRUIT GARDENS

2.1.Plant Parasitic Nematodes in Stone Fruit Orchards

Various nematode species cause yield losses as well as other pests in stone fruit production areas. The most common of these is the root-knot nematode, ring nematodes, root-lesion nematodes, dagger nematodes (Table 1) (Table 2).

Table 1: Widespread Plant Parasitic Nematode Species and Damage Types in Peach, Nectarine, Apricot, Plum Orchards

Peach, Nectarine, Apricot, Plum	
Nematode species	**Comments**
M. incognita, *M. javanica* (Root-knot nematodes)	They cause severe damage, especially in sandy soils. In addition, it prevents water and plant nutrient intake in the plant with the galls they form in the roots. If the seedlings are planted on soils contaminated with pests, growth retardation is observed in the trees in a short time (Ertürk et al., 1975). The most common root knot nematode species *M. incognita* and *M. javanica* were determined in peach growing gardens in the Aegean Region of Turkey (Yağcı and Kaşkavalcı, 2018). Resistant rootstocks such as Garnem, M-29 and Cadaman should be used in areas which is contaminated with root knot nematodes (Yağcı et al., 2019).
Criconemella xenoplax *(*Ring nematodes)	They cause necrosis and blackening on the roots. In addition, they feed on the root tips for that reason it prevents growth and causes serious weakening of the tree. Seedlings are planted in the contaminated areas, one year after there is an eighty percent decrease in the roots and the plants die after 3-7 years. Ring nematode tolerant Guardian rootstock should be used in contaminated areas.
Pratylenchus spp. (Root-lesion nematodes)	They cause necrosis or darkening of the roots and weakening of the roots. They facilitate the entry of bacterial and fungal agents into the plant. It was determined that *Pratylenchus thornei, P. neglectus, P. penetrans, P. crenatus* species are found in Turkey and *P. neglectus* is the most common species among them (Kepenekçi, 2001; Kepenekçi et al., 2001).
Xiphinema americanum (Dagger nematodes)	There is no direct damage to the trees. But they carry the factors of diseases that cause the death of trees. For example, *Xiphinema americanum* carries virus types such as Peach rosette mosaic virus and tomato ringspot virus, which causes yellow mosaic disease in peach and causes the death of the plant.

(Anonymous, 2014a)

Table 2: Widespread Plant Parasitic Nematode Species and Damage Types Cherry and Sour Cherry Orchards

Cherry, Sour Cherry	
Nematode species	**Comments**
X. americanum (Dagger nematodes)	*X. americanum* carries the Cherry Rasp Leaf Virus (CRLV) which is a problem in cherry orchards. The virus causes deformations on the undersides of cherry leaves.
Pratylenchus pentrans (Root-lesion nematodes)	As a result of their feeding, it causes necrosis in the roots of the cherry trees or the death of the roots and weakens the trees.

(Nyczepir & Halbrendt, 1993)

2.2. Plant Parasitic Nematodes in Pome Fruit Orchards

Nematodes parasitize tree roots, reducing tree vigor and causes crop yield. It makes trees susceptible to various disease and transmits viruses. Different nematode species reduce production in pome fruit orchards (Table 3).

Apple, Pear, Quince	
Nematode species	**Comments**
M.incognita, M.hapla, M.javanica (Root-knot nematodes)	As a result of their feeding the galls formed on roots and they prevent the plant from taking up water and nutrients from the soil.
Pratylenchus spp. (Root-lesion nematodes)	As a result of the interaction of lesion nematodes with other soil-borne microorganisms, the damage to the roots increases in contaminated areas. Evlice (2005) found that most common species were Pratylenchus alkani, P.penetrans in Ankara province of Turkey. Söğüt &Devran (2011) reported that *P. thornei* and *P. neglectus* species were the most common lesion nematodes in fruit fields in the Western Mediterranean Region

	of Turkey, while *P. penetrans* and *P. crenatus* species were found in certain regions.
X. americanum (Dagger nematodes)	They are harmful in young trees as a result of feeding with their long stylets, but the main damage is the tomato ringspot virus, which causes necrosis and weakening in apple trees. The severity of the nematodes increases, especially on some susceptible rootstocks.

Table 3: Widespread Plant Parasitic Nematode Species and Damage Types Apple, Pear, Quince Orchards

(Crow & Rich, 2009b) (Anonymous, 2014b)

2.2. Plant Parasitic Nematodes in Berry Orchards

There are plant parasitic nematodes that can cause serious damage to berry orchards. These nematodes not only affect the vigor of the plant, but can also transmits viruses. Therefore, it is very important to identfy nematode species in gardens (Table 4, Table 5, Table 6).

Table 4: Widespread Plant Parasitic Nematode Species and Damage in Vineyards

Vineyard	
Nematode species	**Comments**
Tylenchulus semipenetrans (*Citrus nematodes*)	At high population density, they weaken the tree by feeding on the roots.
Criconemella xenoplax (Ring nematodes)	*C. xenoplax* extract plant nutrients from plant roots with their long stylets. Vines weaken at high population density.
Pratylenchus vulnus (Root lesion nematodes)	*P. vulnus* cause darkening and necrosis on the roots.

Xiphinema index, X.americanum (Dagger nematodes)	They do not settle at the root, but insert their long stylets into the deepest parts of the roots. *Xiphinema* index carries Grapevine fanleaf virus, which causes crop losses in vineyards. In addition, this factor feeds directly on the roots in the absence of the virus, causing significant damage to the vineyard areas. *X. index* virus disease is accompanied by yellowing on the leaves of the vines, double leaves, double leeches, shortening of the internodes, fan leafiness, stunting on the vines, flattening on the sticks, small clusters and large and small grains. As a result of weakening, stagnation and decrease in yield in vines, it causes 30-40% damage in vineyards. Seven dagger nematode species have been identified in Turkey (Karakaş, 2013).

(Bird & Melakeberhan, 1993)

Table 5: Widespread Plant Parasitic Nematode Species and Damage in Vineyards

Kiwi	
Nematode species	**Comments**
	Especially in sandy soils, they prevent the growth of the plant as a result of their feeding. They cause crop losses in fruit trees at high populations. Akyazı & Felek (2013) determined that *M. incognita* was the most common species in their study in kiwi orchards in Ordu province in Turkey.

(Hussey & Janssen, 2002)

Table 6: Widespread Plant Parasitic Nematode Species and Damage in Strawberry Fields

Strawberry	
Nematode species	**Comments**
M. hapla (Root-knot nematodes)	They cause scattered roots to occur in the roots, bleaching of the plant, growth retardation and stress.

Aphelencoides fragariae (Strawberry leaf nematodes)	It is more common in tropical and temperate regions. In the contaminated areas, deformations in the flowers, buds and leaves of the plant, shortening and redness of the petioles occur. Highly contaminated plants do not produce fruit and cause significant yield reduction. This nematode is found in the Black Sea Region of Turkey. Zonguldak and Bartın, Bursa in the Marmara Region, Yalova and Istanbul, Mersin in the Mediterranean Region determined in strawberry fields (Kepenekci & Öztürk, 2002; Anonymous, 2017).
Pratylenchus penetrans (Root-lesion nematodes)	They are potential pests.
X. diversicaudatum (Dagger nematodes)	*X. diversicaudatum* is the vector of Strawberry Latent Ringspot Nepovirus on strawberry.

(Dicker, 1948; Franklin, 1982)

2.4. Plant Parasitic Nematodes in Subtropical Orchards

Plant-parasitic nematodes cause many problems on a number of tropical fruit tree crops (McSorley, 1992). Nematodes cause production reduce at different scale (Table 7; Table 8; Table 9; Table 10).

Table 7: Widespread Plant Parasitic Nematode Species and Damage in Pomegranate and Mulberry Orchards

Pomegranate and Mulberry	
Nematode species	**Comments**
M.incognita, M.javanica (Root-knot nematodes)	Due to the galls formed on the roots as a result of their feeding, growth reduction on the plant, especially in sandy soils. They cause significant damage in contaminated pomegranate and mulberry orchards.

(Crow & Rich, 2009a)

Table 8: Widespread Plant Parasitic Nematode Species and Damage in Citrus Orchards

Citrus	
Nematode species	**Comments**
Tylenchulus semipenetrans (*Citrus* nematodes)	In trees, physical activities such as water and nutrient intake are disrupted. Shrinkage, discoloration and bushiness are seen on citrus leaves. Root development slows down. As a result of the pest feeding on the roots, the roots rot quickly. Infected trees remain smaller and less productive than healthy trees. (Pehlivan,1995). In the study carried out in the citrus orchard in Adana, it was determined that the nematode caused 10% yield loss (Toktay & Elekcioğlu, 2001).
Pratylenchus penetrans (Root-lesion nematodes)	It creates lesions as a result of feeding. The growth of the tree slows down.
Xiphinema americanum (Dagger nematodes)	In the gardens where the infection is intense, the thin branches dry out and the leaves become smaller.

(Duncan et al., 2014)

Table 9: Widespread Plant Parasitic Nematode Species and Damage in Banana Orchards

Banana	
Nematode species	**Comments**
Helicotylenchus multicinctus (Spiral nematodes)	Spiral nematode harms all its hosts as an ectoparasite. However, it is an endoparasite only in bananas. It causes damage by entering from different parts of the banana roots. The damage caused by this nematode is easily understood by the wounds on the banana roots. Visible brown spots are formed on the cortex layer of the plant root damaged by the nematode. Nematodes damage epidermis tissues. But they do not penetrate deeply into plant tissue. Damaged tissues form wound areas. As a result of the damage, the development of bananas is prevented, the lengths are reduced, the trunk softens and the leaves turn yellow. The expected product cannot be obtained because the bunches of

	bananas cannot develop sufficiently. If the garden is infested with other nematode species such as root-knot nematode, the severity of the damage increases. These nematodes cause 20% damage to bananas in the Mediterranean Region of our country (Anonymous, 2008).
Meloidogyne spp. (Root-knot nematodes)	They prevent the development of banana roots by settling in, damaging the roots and absorbing the plant sap. They cause galls to form on the roots. In addition, they cause the development of fungal diseases in the wounds they open on the root. Plant roots damaged by nematodes appear as colorless, visible brown spots.
Radopholus similis (Burrowing nematodes)	They cause very severe decay by making holes in the root tissues. They are the most dangerous parasites of banana roots. large spots of red and black color occur on the roots and over time these cause the whole root to rot. Often the contamination is so severe that with the plant being knocked down, all production can be lost.

(Anonymous, 2004; Tzortzakakis, 2008)

Table 10: Widespread Plant Parasitic Nematode Species and Damage in Fig Orchards

Fig	
Nematode species	**Comments**
Heterodera fici (Fig cyst nematodes)	Plants in soils infected with fig cyst nematode generally become stunted, weaken the growth of the plant, and decrease in fruit yield and size. Bushes are seen due to the damage of the nematode on the roots. Female nematodes feeding on thin roots damage the roots after a while. However, the population density of Fig cyst nematode usually does not reach very high levels (Anonymous, 2008).
Meloidogyne incognita, M. javanica (Root-knot nematodes)	As a result of the damage of the nematode, the development of the fig trees slows down over time and dies. The life period of plants can be extended by some cultural practices. New trees to be planted should be planted in areas further away from the old infested gardens. Figs should not be planted in soils where root-

	knot nematodes are present. Özaraslandan (2009) found that *M. incognita* species in fig orchards in Adana province.
Pratylenchus vulnus (Root-lesion nematodes) *Xiphinema index* (Dagger nematodes)	They do not cause economic damage on fig trees. Trees weaken in areas where the population level is high.

3. CONTROL OF PLANT PARASITE NEMATODES IN FRUIT ORCHARDS

3.1. Cultural Prevention

- The soil in the area where the garden will be established should be analyzed for the presence of nematodes.
- Certified rootstock should be used.
- If the land where the garden will be established is contaminated with plant parasitic nematodes, future nematode damage can be tolerated by soil fumigation.
- The most important factor in the control of nematodes in orchards is to carefully examine the seedlings taken from the nurseries before the orchards are established, and the seedlings with gall roots should never be used.
- Rootstock varieties resistant to nematode species should be selected for the areas where the garden will be established.
- By adding organic substances to the soil, the physical and chemical structure of the soil can be improved. Trees can be made more tolerant to nematodes by stimulating tree growth with compost or fertilizer supplementation.

- Care should be taken to ensure that the water used in the gardens is clean. In addition, drip irrigation method should be preferred in gardens.
- Non-host plants such as cereals should be grown for at least 3 years in gardens where dagger nematodes are infested.
- The biological activity of the soil should be increased by mixing farm manure and organic materials into the soil.
- Trees should not be under water stress. Weed control should be done in gardens (Nycziper, 1991; Crow & Rich, 2009).

3.2. Physical Control

The nematode population in the soil can be reduced with the solarization application that lasts 6-8 weeks in the hot summer months before the garden is established. The population of Strawberry nematode can be reduced by keeping the seeds in water at room temperature (20 °C) for 16–20 hours and then keeping them in water at 51 °C for 7 minutes. Contaminated seeds can be kept in water at 55–60 °C for 10-15 minutes without soaking.

3.3. Biological Control

Natural enemies of plant parasitic nematodes; entomopathogenic fungi, bacteria, protozoa, rickettsia, predatory nematodes, mites and collembola.

3.4. Quarantine Precautions

The entry of nematodes on quarantine lists on plant or soil material into countries should be prevented.

3.5. Chemical Control

In order to be successful in chemical control with nematodes, cultural precautions must be taken well. Soil fumigation should be done with nematicides before planting in the gardens. After planting, pesticides can be used depending on the intensity of the pest. In the selection of nematicides, the plant is sprayed with a registered nematicide (Anonymous, 2014c).

REFERENCES

Akbay, C., Candemir, C.S., & Orhan, E. (2005). Fresh Fruit and Vegetables Production and Marketing in Turkey. KSU. Journal of Science and Engineering 96 8(2): 96-107.

Akyazı, F. & Felek, A. (2013). Population fluctuations of root-knot nematode species *Meloidogyne incognita* in kiwifruit orchards in Ordu province, Turkey. Academic Journal of Agriculture, 2(2): 75-82.

Anonymous, (2004). http://www2.ctahr.hawaii.edu/adap/ASCC_LandGrant/Dr_ Brooks/ BrochureNo9.pdf. (Access date: 20.03.2015)

Anonymous, (2008). Plant Protection Technical Instructions. Cilt 6. https://www.tarimorman.gov.tr/Konu/962/Zirai-Mucadele-Teknik-Talimatlari

Anonymous, (2014a). http://www.hortgro-science.co.za/wp-content/uploads/ Nematodes-in Stone-Fruit.pdf (Access Date: 03.04.2015)

Anonymous, (2014b) http://www.hortgro-science.co.za/wp-content/uploads/ Nematodes-in-Pome-Fruit.pdf. (Access Date: 22.03.2015)

Anonymous, (2014c). http://www.tarim.gov.tr/Konular/Bitki-Sagligi-Hizmetleri/ Zirai-Karantina. (Access Date: 21.04.2015)

Anonymous, (2017). Strawberry Nematode, General Directorate of Agricultural Research and Policies, Department of Plant Health Research, Plant Protection Technical Instructions, Volume: 6, pp: 20-22.

Bird, G.W. & Melakeberhan, H., 1993. Avoidance and Management of Nematode Problems in Tree Fruit Production in Michigan. Extension Bulletin E-2419. Michigan University.

Crow, W.T. & Rich, J. (2009). Nematodes of Backyard Deciduous Fruit and Nut Crops in Florida. Publication ENY-055/NG044. Universty of Florida IFAS Extension.

Crow, W.T. & Han, H. (2005). Sting nematode. The Plant Health Instructor. DOI: 10.1094/PHI-I-2005-1208-01.

Dicker, G.H.L. (1948). A preliminary report on the strawberry eelworm (*Aphelenchoides fragariae* Ritzema Bos). Report of the East Malling Research Station, England 1947, pp: 144-147.

Dickerson, O.J., Blake, J.H., & Lewis, S.A. (2000). Nematode Guidelines for South Carolina. Clemson University Cooperating with US. Department of Agriculture, Extension Service Circ. 703, South Carolina, pp: 36.

Dullahide, S.R., Stirling, G.R., Nikulin, A. & Stirling, A.M. (1994). The role of nematodes, fungi, bacteria, and abiyotic factors in the etiology of apple replant problem in the granite belt of Queensland. Australian Journal of Experimental Agriculture, 34.

Duncan L.W., Noling, J.W., & Inserra, R.N. (2014). Florida Citrus Pest Management Guide: Nematodes. ENY-606 Universty of Florida IFAS Extension.

Duncan, L.W. & Eissenstat, D.M. (1993). Responses of *Tylenchulus semipenetrans* to *Citrus* fruit removal: Implications for Carbohydrate Competition. Journal of Nematology, 25(1): 7-14.

Ertürk, H., Özkut, S., & Borazancı, N. (1975). Investigation of resistance of nemaguard peach rootstock to root-knot nematode species (*Meloidogyne incognita* and *Meloidogyne javanica*) in Aegean Region. Plant Protection Bulletin, Vol. 15, No. 1.

Evlice, E. & Öktem, E. (2005). Plant parasitic nematodes of *Tylenchida* (Nematoda) associated with pear (*Pyrus communis* L.) orchards in Ankara district. . Plant Protection Bulletin, 48(4):1-8.

Franklin, M.T. (1982). Aphelenchoides and Related Genera. In: Plant Nematology (Ed: Southey, J.F.). Ministry of Agriculture, Fisheries and Food London, pp: 172-177,

Hussey, R.S. & Janssen, W. (2002). Root-Knot Nematodes: *Meloidogyne* Species, 43-70. In: Plant Resistance to Parasitic Nematodes (Eds: Starr, J.L., Cook, R., & Bridge, J.). CABI Publishing, Biddles Ltd, UK. pp: 258.

Karakaş, M. (2013). Population density of dagger nematode, *Xiphinema index* (Dorylaimida: Longidoridae) in vineyards in Manisa, Turkey MAKÜ FEBED, 4(2): 8-12.

Kepenekci, İ & Öztürk G. (2002). Strawberry *Fragaria* sp. plant parasitic nematode species detected in Göksu/İçel. IV. Vegetable Agriculture Symposium.

Kepenekçi, I. (2001). Plant parasitic nematodes of *Tylenchida* (Nematoda) associated with stone fruits (Apricots and Peaches) in Southern Turkey. Pakistan Journal of Nematology, 19: 49–61.

Kepenekçi, İ., Öztürk, G., & Akgül, H.C. (2001). Plant parasitic nematodes belonging to the order *Tylenchida* (Nematoda) detected in plum (*Prunus domestica* L.) orchards in the Black Sea and Mediterranean Regions. Turkey I. Seed Fruits Symposium, 25-28 September 2001. Yalova, Proceedings, pp: 509-518.

McSorley, R. (1992) Nematological problems in tropical and subtropical fruit tree crops. Nematropica, 22: 103–116.

Mcsorley, R. & Parrado, J.L. (1983). The spiral nematode, *Helicotylenchus multicinctus*, on bananas in Florida and its control. Proc. Fla. State Hort. Soc. 96: 201-207.

Nycziper, A.P. & Halbrendt, J.M. (1993). Nematode Pests of Deciduous Fruit and Nut Trees. In: Plant Parasitic Nematodes in Temperate Agriculture. Evans, K., Trudgill, D. L., & Webster, J.M. (eds.). CAB International, Wallingford, England. pp: 381-425.

Özarslandan, A. (2009). Identification of *Meloidogyne* species collected from different parts of Turkey and determination of virulence of some root-knot (*Meloidogyne* spp.) populations. Doctorate Thesis. Çukurova University, Institute of Science and Technology, Department of Plant Protection, Adana. pp: 94.

Pehlivan, E. (1995). Nematology. Ege University Faculty of Agriculture Publications Lecture Notes No: 35, E.Ü. Faculty of Agriculture Offset Printing House Bornova-İzmir, pp:78.

Siddiqi, M.R. (1975). *Aphelenchoides fragariae*. C.I.H. Descriptions of Plant-parasitic Nematodes, Set 5, No. 74. Wallingford, UK: CAB International, pp: 4.

Söğüt, M.A. & Devran, Z. (2011). Distribution and molecular identification of root lesion nematodes in temperate fruit orchards of Turkey. Nematropica, 41(1): 91-99.

Toktay, H. & Elekcioğlu, İ.H. (2001). Population fluctuation of *Tylenchulus semipenetrans* Cobb (Nemata, Tylenchulidae) and its effect on yield of Washington Navel orange in the Eastern Mediterranean Region. Proceedings of the 4th Entomology Congress of Turkey, Aydın. pp: 237-246.

Tzortzakakis, A.E. (2008). Plant parasitic nematodes associated with banana crop in Crete, Greece. Acta Agriculturae Slovenica, 91(1): 97-101.

Utkhede, R.S., Smith, E.M., & Palmer, R. (1992). Effect of root fungi and root-lesion nematodes on the growth of young apple trees grown in apple replant disease soil. Zeitschrift fur Pflanzenkrankheiten und Pflanzen Schutz, 99(4): 414-419.

Whitehead, A.G. (1998). Plant Nematode Control. CAB International, New York, USA. pp: 209-236.

Yagci, M. & Kaşkavalcı, G. (2018). Distribition and identification of root-knot (*Meloidogyne* spp.) species in peach growing areas of Aegean Region. Ege Journal of Agricultural Research, 5(3): 305-310.

Yagci, M., Kaşkavalcı, G., & Devran, Z. (2019). Reaction of peach and nectarine rootstocks to different populations of root-knot nematode species, *Meloidogyne incognita* (Kofoid & White, 1919) and *Meloidogyne javanica* (Treub, 1885). Turkish Journal of Entomology, 43(2): 171-178.

CHAPTER VI

USE OF IN VITRO TISSUE CULTURE IN FRUIT BREEDING STUDIES: SOMACLONAL VARIATION, EMBRYO AND ANTHER CULTURE METHODS

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INTRODUCTION

Fruit cultivation has formed the basis of the transition to settled life and has an important place in the cultural history of humanity. Fruit crops are high in vitamins, minerals, antioxidants and also consume fresh and processed products in other products, making them significant for human consumption. World fruit production increased to 883.4 million metric tons in 2019 (FAO, 2021).

With the transition to settled life, people continued to produce fruits with good quality and high yield, and laid the foundations of breeding with natural selection. Selection breeding is still an important step in all breeding methods. The increase in the world population and the global climate crises have brought the breeding of fruit varieties with different characteristics (resistance to diseases, pests and drought, high yield quality, etc.) to the fore.

Traditional fruit breeding has many limits because of the biological characteristics common to perennial woody plants, such as long juvenile period, self-incompatibility, and high heterozygosity. In addition to these technical limits, there are financial difficulties such as the establishment of trials on large areas and labor intensity. In recent years, to avoid these limitations, plant tissue culture methods have been widely used due to the intensive use of technology and lower input prices especially in good laboratory infrastructure conditions.

Plant tissue culture is an important technique that allows obtaining new plants from cells, protoplasts, tissues and organs under aseptic and controlled environmental conditions (Thorpe, 2007). This technique is based on totipotency and plasticity capability of plant cells (Haberlandt, 1902; Takebe et al., 1971; Cassells & Gahan, 2006; Thorpe, 2007). Nowadays it has found a great number of usage area in fruit crops not only massive micro propagation, micro grafting, virus elimination, and conservation of plant genetic resources, but also fruit breeding such as embryo culture, development of transgenic plants, *in vitro* mutagenesis, somaclonal variation, anther culture, and in vitro pollination (Shi et al., 1992; Höfer, 1997; Lespinasse et al., 1998; Germanà et al., 2001; Paunovic et al., 2007; Isac et al., 2010; Rafail & Mosleh, 2010; Eroğlu et al., 2012; Carrasco et al., 2013; Sulusoglu, 2012; Sulusoglu & Cavusoglu, 2013; Ge et al., 2015; Şahin et al., 2016; Şahin & Doğan, 2019; Perez-Jimenez et al., 2020; Dogan et al., 2021).

In this section, scope, importance and current status of somaclonal variation, embryo and anther culture methods that used in the breeding of fruit species were evaluated.

1. SOMACLONAL VARIATION

Somaclonal variation is hereditary changes that occur as a result of genetic instability in plant tissue culture (Larkin & Scowcroft, 1981). While this is seen as a serious issue in the commercial sector at micro propagation stage since it can affect uniformity, it has been seen to be an important tool for breeding. Because variability status of studied

population is very important in the development of new varieties with desired characteristics and also with this method, populations with high variation can be obtained in a short time.

Comprehensive studies have been conducted to understand the nature of genetic modifications responsible for somaclonal variation and it has been determined that they are associated with complex mechanisms (Cassells & Curry, 2001; Predieri, 2001). But factors causing somaclonal variation can be grouped under two main heading; numerical and structural changes in chromosomes and changes in genes (Tosun & Sağsöz, 1995). In addition, factors affecting the frequency of somaclonal variation in *in vitro* culture can be listed as species, type of tissue used as starting material, culture medium, hormone concentrations, number of subcultures, and age of culture (Table 1) (Tosun & Sağsöz, 1995; Hashemi-petroudi et al., 2018; Solano et al., 2019).

Phenotypic (based on morphological and physiological observation) and genotypic (DNA analysis) identification methods are used to determine the resultant somaclonal variation. Although sometimes variation can be determined very easily, in some cases it is not always possible to determine the variations at the phenotypic level because some features cannot be understood from outside. In these cases, use of DNA markers such as SSR, ISSR, IRAP, RAPD, AFLP, RFLP is seen successful tool to obtain variation in perennial plants including fruit species (Schneider et al., 1996; Rahman & Rajora, 2001; Pew & Deng,

2005; Palombi et al., 2007; Khorshidi et al., 2017; Kohpaii et al., 2017; Hashemi-petroudi, et al., 2018; Solano et al., 2019; Mirani et al., 2021).

Somaclonal variants have been reported in fruit species such as peach, apple, pear, quince, sour cherry, strawberry, vitis, and pineapple since the 1980s (Viseur & Figueroa, 1987; Ochatt & Power, 1989; Hammerschlag, 1990; Dolcet-Sanjuan, 1991; Hammerschlag, 1992; Donovan et al., 1994; Önal, 2000; Marino & Molendini, 2005; Palombi et al., 2007; Bustamante et al., 2017; Karim et al., 2015; Dhurve et al., 2021). It has been determined that the obtained somaclonal variants have important properties including resistance to both biotic and abiotic stress conditions. For example, two somaclonal quince variants were selected with higher leaf chlorophyll content from 2000 quince shoots derived from leaf discs (Dolcet-Sanjuan, 1991; Dolcet-Sanjuan et al., 1992; Bunnag et al., 1996). In addition, NaCl tolerance or tolerance to calcareous soils in sour cherry kiwifruit, quince and pear variants, (Ochatt & Power, 1989; Caboni et al., 2003; Cinelli et al., 2004; Marino & Molendini, 2005), tolerance to Fe-chlorosis in wild pear variants (Palombi et al., 2007) have been reported. On the other hand, bacterial leaf spot resistance in peach variants (Hammerschlag, 1990), fire blight resistance in apple and pear variants (Viseur & Figueroa, 1987; Donovan et al., 1994). Also these variants have formed the basis of many studies. The summary information about the studies on these subjects is as in the Table1.

Table 1: Examples from Studies on Somatic Variation in Fruit Species

Species	**Explant type**	**Medium-Growth regulator**	**Name of SV***	**Obtained feature**	**Ref****
Morus alba	Internodal segments	MS BAP, 2,4-D, NAA	SV1	Better leaf yield	Narayan et al., 1989
Malus domestica	Leaf discs	C81 BAP, NAA	-	Resistance to *Erwinia amylovora* (Fire blight disease)	Donovan et al., 1994
Citrus limon	-	-	FS 01, FS 11	Tolerant to *Phoma tracheiphilla* (Mal Secco)	Gentile et al., 1998
Musa spp.	Shoot tips	MS BA	CIEN BTA-03	Resistant to Yellow Sigatoka disease	Giménez et al., 2001
Fragaria x Ananassa	Leaf and petiole	MS BAP, NAA	CP-ScIII, FA-Mu5	Better than parent for all studied vegetative characters	Kaushal et al., 2004
Fragaria x Ananassa	Meristem culture, micropropagation, direct organogenesis, regeneration from callus, somatic embryogenesis	MS BAP, GA_3, 2,4-D	Variant 1, Variant 2, Variant 3	Better horticultural features	Biswas et al., 2009

*SV: Somaclonal Variant, **Ref.: References

Table 1. Continued

Species	Explant type	Medium-Growth regulator	Name of SV*	Obtained feature	Ref.**
Fragaria x Ananassa	Leaf explants	MS, ½ MS BA, 2,4-D, NAA, KIN	RABI-1, RABI-2, RABI-3	Better horticultural features	Karim et al., 2015
Vitis vinifera	-	-	Pink Globe	Earlier ripening, sweeter taste, lighter skin color, and thinner skin, lower anthocyanin content	Bustamante et al., 2017
Prunus avium	Leaf explants, shoots	-	HS	Lower vegetative vigor, less crowded canopy, higher accumulation of flavonoids in fruits	Piagnani et al., 2002; Piagnani et al., 2005; Piagnani et al., 2008; Prinsi et al., 2016
Ananas comosus	Shoot tip	MS BA, NAA	T4, T17 T71, T47, T43, T25, T26, T22, T24, T75, T10, T69	Promising somaclones with high selection indices	Dhurve et al., 2021
Punica granatum	-	-	-	Prominent crown neck, dark red aril, Different leaf characteristics (Leaf blade shape, Leaf apex shape), high anthocyanin	Sridhar et al., 2019

*SV: Somaclonal Variant, **Ref.: References

1.1. Embryo Culture

Embryo culture method, which is examined under two main headings as mature and immature embryo (embryo rescue) culture, based on growing of zygotic embryos interrupted from ovules and/or seeds in suitable medium under aseptic conditions (Figure 1). When the goal is embryo rescue, it is essential to determine the stage at which the embryo degeneration develops and the embryo is allowed to grow inside before the abortion starts (Bhojwani & Dantu, 2013).

Figure 1: Embryo Culture of the Methley Plum Cultivar (Şahin et al., 2016)

The first successful embryo culture was obtained from mature embryos of two crucifers (*Raphanus* spp. and *Cochlearia danica*) by E. Hanning in the early 1900's (Narayanaswami & Norstog, 1964). When the studies on fruit species were examined, it is seen that the first embryo culture study was done on *Prunus avium* and it is stated as a milestone

for fruit species (Tukey, 1933). Nowadays, this method is widely used to break seed dormancy, to overcome the barrier of embryo abortion seen in intraspecies and interspecies hybrids, early ripening varieties, and plants at different ploidy levels (Norstog, 1979; Ramming, 1990; Chee, 1994; Arbeloa et al., 2003; Viloria et al., 2005; Arbeloa et al., 2009).

The success of embryo culture depends on a number of factors such as species, genotype, ingredients of culture media, hormone concentrations, maturity state of embryos, embryo sizes, and chilling times (Scozzoli & Pasini, 1992; Burgos & Ledbetter, 1993; Emershad & Ramming, 1994; Küden et al., 1999; Anderson et al., 2002; Arbeloa et al., 2003; Sinclair & Byrne, 2003; Srivastav et al., 2004; Viloria et al., 2005; Arbeloa et al., 2009; Şan et al., 2014; Ghayyad, 2018; Mitrofanova et al., 2019; Ren et al., 2019; Zhu et al., 2020; Wu et al., 2021).

Germination of each seed obtained from hybridization studies is very important because it is at risk to reach the desired properties with each individual that does not germinate. In case of appropriate laboratory infrastructure, not only germination rates of hybrid seeds can be increased but also hybrid success will improve. This is supported by the studies carried out. In the study where seed germination in greenhouse conditions, in vitro seed germination and isolated embryo culture were tested in apricots, the germination percentages were determined as 50, 75, 85%, respectively, and isolated embryo culture came to the fore with the highest germination rate (Yildirim et al., 2007). In addition, by

obtaining a large number of plants from a single embryo with using different hormone concentrations, the selection process can be shortened, thus saving both labor and time (Şahin et al., 2016). Embryos of fruit species can grow on a solid or semi-solid MS (Murashige & Skoog, 1962) and Gamborg's B5 medium (Gamborg et al., 1968) mediums with different plant growth regulators combinations and doses. In line with the findings of Şahin et al., (2016), it was determined that especially in cases where replication of hybrid plants is important, media with high BAP content can be preferred but it should not be ignored that rosette plant formation can increase (Rizzo et al., 1998; Jeengool & Boonprakob, 2004; Şahin et al., 2016).

1.2. Anther Culture

In recent years, haploidy technique, which is one of the biotechnological methods and has an important place in hybrid seed breeding, is widely used in many plant species, including fruit species (Şahin & Doğan, 2019). As it is known, breeding of fruit species with high heterozygosity by classical breeding methods includes long-term studies. In these species, haploidization by conventional methods is very difficult due to high heterozygosity, long juvenile sterility period and self-incompatibility (Germanà, 2005). Thanks to the anther culture method, full homozygosity is obtained in a very short time (Jain et al., 1997) and thus the breeding period can be shortened. To date, haploid plants have been obtained from 200 plant species and some of these plants have been successfully multiplied to form double haploid plants (Forster et al., 2007).

Haploid plants are developed by androgenesis and gynogenesis methods. In androgenesis, haploid plant formation takes place from anthers and pollen, and in gynogenesis, from ovules and ovaries. Anther culture technique, which is one of these methods that allows obtaining haploid lines in a short time, is widely used in fruit breeding. The next stage after obtaining haploid plants is the doubling of the chromosome numbers with the help of some chemical substances (Tıpırdamaz & Ellialtıoğlu, 2002) especially colchicine.

Studies on obtaining haploid plants in fruit trees began in the 1970s, focusing on the in vitro androgenesis method in stone and pome fruit species (Zhang et al., 1989). Species, varieties, tree age, flower bud uptake date, pollen development period, temperature, light, nutrient media, components added to the nutrient medium such as activated carbon and some plant extracts, sources of sucrose, plant growth regulators and concentrations, agar sources and callus age are important factors that affecting callus, embriyo and plant formation (Stiles et al., 1980; Hidano, 1982; Hassawai & Liang 1990; Jaramillo & Summers, 1991; Arrillaga et al., 1995; Mićić et al., 1996; Kadota et al., 2002; Kadota & Niimi, 2004; Germanà, 2005; Perera et al., 2009; Smýkalová et al., 2009; Germanà et al., 2011; Nguyen et al., 2012; Şahin & Doğan, 2019). Detailed information is given in Table 2.

Table 2: Anther Culture Studies of Important Fruit Species

Species	**Medium-Growth regulator-Treatment**	**Obtained material**	**Reference**
Malus pumila	MS IAA, NAA, Kinetin	Callus, embryo	Hidano, 1982
Malus domestica *Pyrus communis*	MS TDZ, Kinetin Cold, light, dark, activated carbon	Callus, plant	Kadota et al., 2002
Malus domestica	N6, MS, ½ MS BAP, NAA, Cold, dark	Callus, embryo, shoot	Zhang et al., 2017
Pyrus pyrifolia	MS, ½ MS BA, IBA Cold, dark, activated carbon	Callus, embryo, shoot	Kadota & Niimi, 2004
Prunus armeniaca	MS, N&N TDZ, IAA, zeatin, GA_3 Dark, temperature	Callus	Peixe et al., 2004
Prunus armeniaca	MS, P, NN4 Zeatin, TDZ Cold, dark	Callus	Germanà et al., 2011
Punica granatumun	MS BA, NAA	Diploid plant from callus	Moriguchi et al., 1987

Table 2. Continued

Species	Medium-Growth regulator-Treatment	Obtained material	Reference
Punica granatumun	MS BAP, NAA, 2,4-D Dark, taken time of flower buds	Callus, root shoot	Şahin & Doğan, 2019
Fragaria x ananassa	MS, B5, H1 BA, IAA, 2,4-D Dark	Callus, shoot, plant	Nguyen et al., 2012
Actinidia arguta	MS NAA, IBA, TDZ, BA, ZT Cold, dark	Callus, shoot, root, plant	Wang et al., 2018
Musa balbisiana	MS with Morel vitamins BAP, IAA	Callus, plant	Assani et al., 2003

CONCLUSION

Breeding of fruit species faces some technical troubles and *in vitro* techniques have seen as an important solution. Somaclonal variation, embryo and anther culture methods were evaluated in this chapter. It is seen that each method is used both as a main method and as an auxiliary method at different stages of breeding. Somaclonal variation emerges as a main method in obtaining individuals resistant to different abiotic and biotic stress conditions, as well as providing the formation of highly diverse populations. Embryo culture gains importance in interspecies

crossings and in combinations in which early varieties are parents, in terms of enabling plant production. It is also possible to reproduce hybrid individuals by using different hormone doses related to this subject. Finally, when the anther culture studies are examined, it is seen that the haploid plant production due to their persistence in cultures is low and mostly callus is formed. New developments in these technologies show promise for their intensive usage in fruit breeding programs and combining them with micropropagation will reduce breeding time.

REFERENCES

Anderson, N., Byrne, D.H., Sinclair, J., & Burrell, A.M. (2002). Cooler temperature during germination improves the survival of embryo cultured peach seed. HortScience, 37(2): 402-403.

Arbeloa, A., Daorden, M.E., García, E., & Marín, J.A. (2003). Successful establishment of in vitro cultures of *Prunus cerasifera* hybrids by embryo culture of immature fruits. Acta Horticulturae, 616: 375-378.

Arbeloa, A., Daorden, M.E., García, E., Andreu, P., & Marín, J.A. (2009). In vitro culture of myrobalan (*Prunus cerasifera* Ehrh.) embryos. HortScience, 44(6): 1672-1674.

Arrillaga, I., Lerma, V., Pérez-Bermúdez, P., & Segura, J. (1995). Callus and somatic embryogenesis from cultured anthers of service tree (*Sorbus domestica* L.). Hortscience, 30(5): 1078-1079.

Assani, A., Bakry, F., Kerbellec, F., Haicour, R., Wenzel, G., & Foroughi-Wehr, B. (2003). Production of haploids from anther culture of banana [*Musa balbisiana* (BB)]. Plant Cell Reports, 21(6): 511-516.

Bhojwani, S.S. & Dantu, P.K. (2013). Plant tissue culture: an introductory text (No. 574.0724/B575). India: Springer.

Biswas, M.K., Dutt, M., Roy, U.K., Islam, R., & Hossain, M. (2009). Development and evaluation of in vitro somaclonal variation in strawberry for improved horticultural traits. Scientia Horticulturae, 122(3): 409-416.

Bunnag, S., Dolcet-Sanjuan, R., Mok, D.W., & Mok, M.C. (1996). Responses of two somaclonal variants of quince (*Cydonia oblonga*) to iron deficiency in the greenhouse and field. Journal of the American Society for Horticultural Science, 121(6): 1054-1058.

Burgos, L. & Ledbetter, C.A. (1993). Improved efficiency in apricot breeding: Effects of embryo development and nutrient media on in vitro germination and seedling establishment. Plant Cell, Tissue and Organ Culture, 35(3): 217-222.

Bustamante, L., Sáez, V., Hinrichsen, P., Castro, M. H., Vergara, C., von Baer, D., & Mardones, C. (2017). Differences in Vvufgt and VvmybA1 gene expression levels and phenolic composition in table grape (*Vitis vinifera* L.) 'Red Globe' and its somaclonal variant 'Pink Globe'. Journal of Agricultural and Food Chemistry, 65(13): 2793-2804.

Caboni, E., Anselmi, S., Donato, E., & Manes, F. (2003). In vitro selection of *Actinidia deliciosa* clones tolerant to NaCl and their molecular and in vivo ecophysiological characterisation. Acta Hortic, 618: 77-83.

Carrasco, B., Meisel, L., Gebauer, M., Garcia-Gonzales, R., & Silva, H. (2013). Breeding in peach, cherry and plum: from a tissue culture, genetic, transcriptomic and genomic perspective. Biological Research, 46(3): 219-230.

Cassells, A.C. & Curry, F.C. (2001). Oxidative stress and physiological, epigenetic and genetic variability in plant tissue culture: Implications for micropropagators and genetic engineers. Plant Cell Tissue Org Cult, 64: 145-157.

Cassells, A.C. & Gahan, P.B. (2006). Dictionary of Plant Tissue Culture. The Haworth Press, New York.

Chee, P.P. (1994). In vitro culture of zygotic embryos of *Taxus* species. HortSci. 29: 695-697.

Cinelli, F., Loreti, F., & Muleo, R. (2004). Regeneration and selection of quince BA29 (*Cydonia oblonga* Mill.) somaclones tolerant to lime-induced chlorosis. Acta Hortic, 658: 573-577.

Dhurve, L., Kumar, K.A., Bhaskar, J., Sobhana, A., Francies, R.M., & Mathew, D. (2021). Wide variability among the 'Mauritius' somaclones demonstrates somaclonal variation as a promising improvement strategy in pineapple (*Ananas comosus* L.). Plant Cell, Tissue and Organ Culture (PCTOC), 145(3): 701-705.

Dogan, S., Sahin, M. & Kaya, O. (2021). Researches on the reproduction of "Ottoman Strawberry" with tissue culture. Alinteri Journal of Agriculture Sciences, 36(1): 27-32.

Dolcet-Sanjuan, R. (1991). Somatic manipulation of *Pyrus* and *Cydonia*: Characterization and selection for iron efficiency. PhD Diss., Oregon State Univ., Corvallis.

Dolcet-Sanjuan, R., Mok, D.W.S., & Mok, M.C. (1992). Characterization and in vitro selection for iron efficiency in *Pyrus* and *Cydonia.* In Vitro Cell. Dev. Biol., 28: 25-29.

Donovan, A.M., Morgan, R., Valobra-Piagnani, C., Ridout, M.S., James, D.J., & Garrett, C.E. (1994). Assessment of somaclonal variation in apple. I. Resistance to the fire blight pathogen, *Erwinia amylovora*. Journal of Horticultural Science, 69(1): 105-113.

Emershad, R.L. & Ramming, D.W. (1994). Effects of media on embryo enlargement, germination and plant development in early-ripening genotypes of *Prunus* grown in vitro. Plant Cell, Tissue and Organ Culture, 37(1): 55-59.

Eroğlu, Ö.Z., Fidancı, A., & Mısırlı, A. (2012). Growth of Immature Embryos on Different Media. Journal of Agricultural Sci, 18: 93-99.

FAO, 2021. http://www.fao.org/faostat/en/#data/QCL. (Access date: 01.09.2021)

Forster, B.P., Heberle-Bors, E., Kasha, K.J., & Touraev, A. (2007). The resurgence of haploids in higher plants. Trends in Plant Science, 12(8): 368-375.

Gamborg, O, Miller, R.A, & Ojima, K. (1968). Nutrient requirements of suspension cultures of soybean root cells. Exp Cell Res, 50: 151-158.

Ge, H., Li, Y., Fu, H., Long, G., Luo, L., Li, R., & Deng, Z. (2015). Production of sweet orange somaclones tolerant to citrus canker disease by in vitro mutagenesis with EMS. Plant Cell, Tissue and Organ Culture (PCTOC), 123(1): 29-38.

Gentile, A., Deng, Z.N., Tribulato, E., Vardi, A., Albanese, G., Grimaldi, V., & Catara, A. (1998). Evaluation of lemon somaclones for tolerance to mal secco disease by artificial inoculation. First International *Citrus* Biotechnology Symposium 535: 259-263.

Germanà, M.A. & Chiancone, B. (2001). Gynogenetic haploids of *Citrus* after in vitro pollination with triploid pollen grains. Plant Cell, Tissue and Organ Culture, 66(1): 59-66.

Germanà, M.A. (2005). Protocol of Somatic Embryogenesis from *Citrus* spp. Anther Culture. Jain, S.M. & Gupta, P.K. (Eds.), in Protocol for Somatic Embryogenesis in Woody Plants, Springer, pp: 191-207.

Germanà, M.A., Chiancone, B., Padoan, D., Bárány, I., Risueno, M. C., & Testillano, P.S. (2011). First stages of microspore reprogramming to embryogenesis through anther culture in *Prunus armeniaca* L. Environmental and Experimental Botany, 71(2): 152-157.

Ghayyad, M.A. (2018). Effects of gibberellic acid and low temperature on germination of some *Prunus* species embryos (without cotyledons) under laboratory conditions. Acta Hortic. Regiotecturae 21(2): 42-47.

Giménez, C., De Garcia, E., De Enrech, N.X., & Blanca, I. (2001). Somaclonal variation in banana: cytogenetic and molecular characterization of the somaclonal variant CIEN BTA-03. In Vitro Cellular & Developmental Biology-Plant, 37(2): 217-222.

Haberlandt, G. (1902). Kulturversuche mit isolierten Pflanzenzellen. Sitzungsber. Akad Wiss Wien Math-Naturwiss Kl Abt J, 111: 69-92.

Hammerschlag, F.A. (1990). Resistance responses of plants regenerated from peach callus cultures to *Xanthomonas campestris* pv. *pruni*. J. Amer. Soc. Hort. Sci, 115: 1034-1037.

Hammerschlag, F.A. (1992). Somaclonal Variation. In: Hammerschlag, F.A. & Litz, R.E. (Eds.). Biotechnology of Perennial Fruit Crops. C.A.B. Intl., Wallingford. Pp: 35-55.

Hashemi-petroudi, S.H., Ghasemi, Y., & Haghpanah, M. (2018). Detection of somaclonal variation in plants regenerated from different tissues of strawberry (*Fragaria x ananassa*) using ISSR marker. Iranian Journal of Genetics and Plant Breeding, 7(2): 65-72.

Hassawai, D.S., Qi, J., & Liang, G.H. (1990). Effects of growth regulator and genotype of production of wheat and triticale polyhaploids from anther culture. Plant Breeding, 104(1): 40-45.

Hidano, Y. (1982). Callus and embryoid induction by anther culture of apple. Bull. Fac. Educ. Hirosaki Univ., 48: 69-74.

Höfer, M. (1997). In vitro androgenesis in apple: Optimization of the anther culture. Acta Hortic, 447: 341-344.

Isac, V., Coman, T., Marinescu, L., Isac, M., Teodorescu, A., Popescu, A., & Plopa, C. (2010). Achievements and trends in the use of tissue culture for the mass propagation of fruit plants and germplasm preservation at the research institute for fruit growing, Pitesti, Romania. Rom Biotech Lett, 15: 92-101.

Jain, S.M., Sopory, S.K., & Veilleux, R.E. (1997). In Vitro Haploid Production in Higher Plants, Vol. 5, Kluwer Academic Publisher, Dordrecht, The Netherlands, London.

Jaramillo, J. & Summers, W.L. (1991). Dark-light treatments influence induction of tomato anther callus. Hortscience, 26(7): 915-916.

Jeengool, N. & Boonprakob, U. (2004). Rescue of peach embryo in culture media with additional of 6-benzyladenine and gibberellic acid. Kasetsart Journal (Natural Science), 38: 468-474.

Kadota, M. & Niimi, Y. (2004). Production of triploid plants of Japanese pear (*Pyrus pyrifolia* Nakai) by anther culture. Euphytica, 138(2): 141-147.

Kadota, M., Han, D., & Niimi, Y. (2002). Plant regeneration from anther-derived embryos of apple and pear. HortScience, 37(6): 962-965.

Karim, R., Ahmed, F., Krishna Roy, U., Ara, T., Islam, R., & Hossain, M. (2015). Varietal improvement of strawberry (*Fragaria x ananassa* Dutch.) through somaclonal variation using in vitro techniques. J. Agr. Sci. Tech. 17: 977-986.

Kaushal, K., Nath, A.K., Kaundal, P. & Sharma, D.R. (2004). Studies on somaclonal variation in strawberry (*Fragaria x Ananassa* Duch.) cultivars. Acta Hortic. 662: 269-275.

Khorshidi, S., Davarynejad, G., Samiei, L., & Moghaddam, M. (2017). Study of genetic diversity of pear genotypes and cultivars (*Pyrus communis* L.) using inter-simple sequence repeat markers (ISSR). Erwerbs-Obstbau, 59(4): 301-308.

Kohpaii, F.N., Farahani, F., & Noormohammadi, Z. (2017). Somaclonal variation in the in vitro regenerated pineapple (*Ananas comosus*): Investigation of the cellular characteristics biochemical specificities and ISSR markers. Phytol. Balc, 23: 73-83.

Küden, A.B., Tanrıver, E., Gülen, H., & Büyükalaca, S. (1999). Embryo rescue of peach hybrids. Acta Horiculturae, 484: 531-533.

Larkin, P.J. & Scowcroft, W. (1981). Somaclonal variation a novel source of variability from cell culture for plant improvement. Theor. Appl. Genet, 60: 197-214.

Lespinasse, Y., Bouvier, L., Djulbic, M., & Chevreau, E. (1998). Haploidy in apple and pear. Acta Hortic, 484: 49-54.

Marino, G & Molendini, L. (2005). In vitro leaf-shoot regeneration and somaclone selection for sodium chloride tolerance in quince and pear. J Hort Sci Biotechnol, 80: 561-570.

Mićić, N., Durić, G., Dublić, M., & Dacić, G. (1996). Haploid induction from anther culture of stone fruits. Acta Agriculturae Serbica, 1(2): 21-30.

Mirani, A.A., Jatoi, M.A., Bux, L., Teo, C.H., Kabiita, A.I., Harikrishna, J.A., … & Channa, G.S. (2021). Genetic stability analysis of tissue culture derived date palm cv. Dedhi plants using IRAP markers. Acta Ecologica Sinica. https://doi.org/10.1016/j.chnaes.2021.02.011

Mitrofanova, I.V., Smykov, A.V., Mitrofanova, O.V., Lesnikova-Sedoshenko, N.P., Chirkov, S.N., & Zhdanova, I.V. (2019). Using in vitro embryo culture for obtaining new breeding forms of peach. IV Balkan Symposium on Fruit Growing, 1289: 159-166.

Moriguchi, T., Omura, M., Matsula, N., & Kozaki, J. (1987). In vitro adventitious shoot formation from anthers of pomegranate. HortScience, 22(5): 947-948.

Murashige, T. & Skoog, F. (1962). A revised medium for rapid growth and bio assays with tobacco tissue cultures. Physiol Plant, 15: 473-497.

Narayan, P., Chakraborty, S. & Subba Rao, G. (1989). Regeneration of plantlets from the callus of stem segments of mature plants of *Morus alba* L. Proceedings of Indian National Science Academy, 55: 469-472.

Narayanaswami, S. & Norstog, K. (1964). Plant embryo culture. The Botanical Review, 30(4): 587.

Nguyen, T.X., Song, Y.S., & Park, S.M. (2012). Haploid plant production through anther culture in day-neutral strawberry (*Fragaria x Ananassa* Duch) cv. Albion. J. ISSAAS, 18(1): 173-184.

Norstog, K. (1979). Embryo culture as a tool in the study of comparative and developmental morphology. In: Sharp, W.R., Larsen, P.O., Paddock, E.F., Raghavan, V. (eds) Plant Cell and Tissue Culture. Ohio State University Press, Columbus, pp: 179-202.

Ochatt, S.J. & Power, J.P. (1989). Selection for salt-drought tolerance using protoplast- and explant-derived tissue cultures of Colt cherry (*Prunus avium* x *pseudocerasus*). Tree Physiol, 5: 259-266.

Önal, K. (2000). A study on the possibilities of creating somaclonal variation by callus culture method in Cruz and Yalova-110 strawberry (Fragia x Ananassa Duch.) cultivars. . Derim, 17(3): 106-112.

Palombi, M.A., Lombardo, B., & Caboni, E. (2007). In vitro regeneration of wild pear (*Pyrus pyraster* Burgsd) clones tolerant to Fe-chlorosis and somaclonal variation analysis by RAPD markers. Plant Cell Reports, 26(4): 489-496.

Paunovic, S., Ruzic, D., Vujovic, T., Milenkovic, S., & Jevremovic, D. (2007). In vitro production of Plum pox virus-free plums by chemotherapy with ribavirin. Biotechnology & Biotechnological Equipment, 21(4): 417-421.

Peixe, A., Barroso, J., Potes, A., & Pais, M.S. (2004). Induction of haploid morphogenic calluses from in vitro cultured anthers of *Prunus armeniaca* cv. 'Harcot'. Plant Cell, Tissue and Organ Culture, 77(1): 35-41.

Perera, P.I.P., Yakandawala, D.M.D., Hoccher, V., Verdeil, J.L., & Weerakoon, L.K. (2009). Effect of growth regulators on microspore embryogenesis in coconut anther. Plant Cell, Tissue and Organ Culture, 96(2): 171-180.

Perez-Jimenez, M., Tallón, C.I., & Perez-Tornero, O. (2020). Inducing mutations in *Citrus* spp.: Sensitivity of different sources of plant material to gamma radiation. Applied Radiation and Isotopes, 157, 109030.

Pew, X.P. & Deng, X.X. (2005). Micropropagation of chestnut rose (*Rosa roxburghii* Tratt) and assessment of genetic stability in in vitro plants using RAPD and AFLP markers. J Hort Sci Biotechnol, 80: 54-60.

Piagnani, M.C., Iacona, C., Intrieri, M.C., & Muleo, R. (2002). A new somaclone of *Prunus avium* shows diverse growth pattern under different spectral quality of radiation. Biol. Plant., 45: 11-17.

Piagnani, M.C., Iacona, C., Intrieri, M.C., & Muleo, R. (2005). A somaclonal variant in 'Hedelfinger' sweet cherry. Acta Hortic., 667: 93-99.

Piagnani, M.C., Maffi, D,. Rossoni, M., & Chiozzotto, R. (2008). Morphological and physiological behavior of sweet cherry 'somaclone' HS plants in field. Euphytica, 160: 165-173.

Predieri, S. (2001). Mutation induction and tissue culture in improving fruits. Plant Cell Tissue Org Cult, 64: 185-210.

Prinsi, B., Negri, A.S., Espen, L., & Piagnani, M.C. (2016). Proteomic comparison of fruit ripening between "Hedelfinger" sweet cherry (*Prunus avium* L.) and its somaclonal variant "HS." Journal of Agricultural and Food Chemistry, 64(20): 4171-4181.

Rafail, S.T. & Mosleh, M.S. (2010). Factors involved in micropropagation and shoot tip grafting of apple (*Malus domestica* Borkh.) and pear (*Pyrus* sp. L.). Tropentag. In: World Food System- A Contribution from Europe, 14–16, September, Zurich.

Rahman, M.H. & Rajora, O.P. (2001). Microsatellite DNA somaclonal variation in micropropagated trembling aspen (*Populus deltoids*). Plant Cell Rep, 20: 531-536.

Ramming, D.W. (1990). The use of embryo culture in fruit breeding. HortScience, 25: 393-398.

Ren, H., Du, X., Li, D., Zhao, A., Wang, Y., Xue, X., ... & Du, J. (2019). An efficient method for immature embryo rescue and plant regeneration from the calli of *Ziziphus jujuba* 'Lengbaiyu'. The Journal of Horticultural Science and Biotechnology, 94(1): 63-69.

Rizzo, M., Bassi, D., Byrne, D., & Porte, K. (1998). Growth of immature peach [*Prunus persica* (L.) Batsch.] embryos on different media. Acta Horticulturae 465: 141-144.

Şahin, M. & Doğan, S. (2019). Effects of taken time of flower buds, dark regime and plant growth regulators on anther culture of pomegranate. ANADOLU ANADOLU Journal of Aegean Agricultural Research Institute , 29(2): 103-113.

Şahin, M., Şafak, C., Çavdar, A., Aksoy, D., & Doğan, S. (2016). Effects of different ms medium on embriyo cultures of some plum and nectarin varieties BAHÇE Special Issue: VII. Proceedings of the National Horticultural Congress - Vol. I: 1142-1146.

Şan, B., Yildirim, A.N., & Yildirim, F. (2014). An in vitro germination technique for some stone fruit species: The embryo isolated from cotyledons successfully germinated without cold pre-treatment of seeds. HortScience, 49(3): 294-296.

Schneider, S., Reustle, G., & Zyprian, E. (1996). Detection of somaclonal variation in grapevine regenerants from protoplast by RAPD-PCR. Vitis, 35(2): 99-100.

Scozzoli, A. & Pasini, D. (1992). Effects of Different Media Constituents on the Development of Peach Embryos Cultured in Vitro. In Vitro Culture, XXIII IHC 300: 265-268.

Shi, Y., Wang, Q., Zhou, G., & Wang, J. (1992). Genome engineering breeding of apple in vitro. Acta Hortic, 317: 13-22.

Sinclair, J.W. & Byrne, D.H. (2003). Improvement of peach embryo culture through manipulation of carbohydrate source and pH. HortScience, 38(4): 582-585.

Smýkalová, I., Smirous, P.Jr., Kubosiová, M., Gasmanová, N, & Griga, M. (2009). Double haploid production via anther culture in annual, winter type of caraway (*Carum carvi* L.). Acta Physiol. Plant, 31(1): 21-31.

Solano, M.C.P., Ruíz, J.S., Arnao, M.T.G., Castro, O.C., Tovar, M.E.G., & Bello, J.J.B. (2019). Evaluation of in vitro shoot multiplication and ISSR marker based assessment of somaclonal variants at different subcultures of vanilla (*Vanilla planifolia* Jacks). Physiology and Molecular Biology of Plants, 25(2): 561-567.

Sridhar, R. & Harish Babu, B.N. (2019). A novel pomegranate (*Punica granatum* L.) variant with high anthocyanin content. Acta Horticulturae, 1255: 149-152.

Srivastav, M., Singh, S.K., Arora, R.L., & Krishna, B. (2004). Embryo culture studies in subtropical peach (*Prunus persica* Batsch.). Acta Hortic. 662: 297-301.

Stiles, H.D., Biggs, R.H., & Sherman, W.B. (1980). Some factors affectıng callus productıon by peach anthers. Proc. Fla. State Hort. Soc., 93: 106-108.

Sulusoglu, M. (2012). Development of embryo culture protocol for cherry laurel (*Prunus laurocerasus* L.). Journal of Food, Agriculture and Environment, 10(3-4): 347-352.

Sulusoglu, M., & Cavusoglu, A. (2013). Micropropagation of cherry laurel (*Prunus laurocerasus* L). J Food Agr Environ, 11, 576-579.

Takebe, I., Labib, C., & Melchers, G. (1971). Regeneration of whole plants from isolated mesophyll protoplasts of tobacco. Naturwissenschaften, 58: 318-320.

Thorpe, T. (2007). History of plant tissue culture. Mol Biotech, 37: 169-180.

Tıpırdamaz, R. & Ellialtıoğlu, Ş. (2002). The effect of cold pretreatment and activated charcoal on the changes in abscisic acid amount during anther culture of pepper (*Capsicum annuum* L.). Journal of Akdeniz University Faculty of Agriculture. 15(1): 9-18.

Tosun, M. & Sağsöz, S. (1995). Somaclonal variation and plant breeding. Journal of Atatürk University Faculty of Agriculture, 26(3): 400-411.

Tukey, H.B. (1933). Embryo abortion in early-ripening varieties of *Prunus avium.* Botanical Gazette, 94(3): 433-468.

Viloria, Z., Grosser, J.W., & Bracho, B. (2005). Immature embryo rescue, culture and seedling development of acid citrus fruit derived from interploid hybridization. Plant Cell, Tissue and Organ Culture, 82(2): 159-167.

Viseur, M.J. & Figueroa, T.M. (1987). In vitro co-culture as a tool for the evaluation of fire blight resistance in pears and apples. Acta Hort, 217: 273-282.

Wang, G.F., Qin, H.Y., Sun, D., Fan, S.T., Yang, Y.M., Wang, Z.X., ... & Ai, J. (2018). Haploid plant regeneration from hardy kiwifruit (*Actinidia arguta* Planch.) anther culture. Plant Cell, Tissue and Organ Culture (PCTOC), 134(1): 15-28.

Wu, Y.J., Song, Q.Q., Yuan, Y., Guo, F.Q., Wu, K.X., & Dong, M.M. (2021). In vitro efficiency of embryo rescue of intra-and interspecific hybrid crosses of sweet cherry and Chinese cherry cultivars. Scientia Horticulturae, 275, 109716.

Yildirim, H., Tilkat, E., Onay, A., & Ozen, H.Ç. (2007). In vitro embryo culture of apricot, *Prunus armeniaca* L. cv. Hacıhaliloğlu. International Journal of Science & Technology, 2(2): 99-104.

Zhang, C., Sato, S., Tsukuni, T., Sato, M., Okada, H., Yamamoto, T., ... & Komori, S. (2017). Elucidating cultivar differences in plant regeneration ability in an apple anther culture. The Horticulture Journal, MI-094.

Zhang, Y.X., Lespinasse, Y., & Chevreau, E. (1989). Induction of haploidy in fruit trees. I. International Symposium on In Vitro Culture and Horticultural Breeding. ISHS Acta Horticulturae, 280: 293-306.

Zhu, P., Gu, B., Li, P., Shu, X., Zhang, X., & Zhang, J. (2020). New cold-resistant, seedless grapes developed using embryo rescue and marker-assisted selection. Plant Cell, Tissue and Organ Culture (PCTOC), 140(3): 551-562.

CHAPTER VII

IN SUSTAINABLE AGRICULTURE: EVALUATION PGPR AND OTHER SOME VIABLE ALTERNATIVE MEDIA COMPONENT AND SOME ORGANIC SUBSTRATES ON ORNAMENTAL PLANTS

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INTRODUCTION

Ornamental plants are to be grown for aesthetic and decorative purpose to meet the spiritual needs of people, of organs such as buds, leaves, branches or itself is used directly. However, this definition has expanded nowadays. Ornamental plants, especially in urban areas, have become the basic material of practices aimed at regulating the relations between human and nature, of practices aimed at eliminating the negative effects of many environmental problems on people and their lives and of applications aimed directly at meeting physical needs.

As it is well known, Covid-19 has emerged as a global threat affecting the world; it has had immediate and unexpected effects on our social and individual lives (Bozkurt et al., 2020). It can be stated that a plus for horticultural plants, especially for ornamental plants, has been revealed for this global crisis. In this case, interest, curiosity and demand for ornamental plants has increased in even more in the conditions during #stayhome, Covid-19. Ornamental plants, which are indispensable materials for the people of our age, are expanding towards the center of our individual and social life day by day. When outstanding and diverse importances of ornamental plants is considered, there is a need to improve the flower quality characteristics of these plants, such as growth and development, flower yield, flower number, longevity and size of flowers, and the aesthetic and functional properties under indoor and outdoor conditions.

To produce high quality ornamental plants, growers have generally concentrated on the use of chemicals (including pesticides and fertilizers) used in agriculture, without taking into account the ornamental plant characteristics and their harmful effects on the environment. Agricultural chemicals used in the cultivation of ornamental plants are expensive and their excessive usage leads to the emergence of pathogens resistant to such that of these chemicals.

Various synthetic fertilizers such as nitrogen, potassium and phosphorus are used at high rates for quality and efficient production in ornamental plants providing a significant financial benefit to growers. In general, the main reasons for fertilizing ornamental plants are to stimulate growth or to obtain strong, healthy, highly quality and aesthetic plants. The excessive cost of chemical fertilizers and the toxic effect of such chemicals on soil microflora and indirectly on human health, are the biggest concerns for growers (Younis et al., 2013). In addition, long-term fertilizer application also destroys the soil structure (Singh et al., 2008) and thus affects on the production and growth of ornamental plants (Torkashvand, 2009). It becomes extremely difficult for growers to manage such threatening situations. Therefore, it has become necessary to develop renewable, cheap and environmentally friendly fertilizers without impairing the quality of ornamental plants. A sustainable and effective alternative method for these purposes is the application of plant growth promoting rhizobacteria (PGPR) at all stages of plant production. The use of PGPR has become an important practice for improving soil yield and quality in many parts of the World

(Fasciglione et al., 2015). The use of PGPR preserves biodiversity and is an inexpensive production input for growers. The broad contributions of PGPR to improving plant growth and health are now well established. PGPR increases in plant growth by a variety of mechanisms such as phosphate solubility, biological nitrogen fixation, 1-aminocyclopropane-1-carboxylate deaminase production (ACC), phytohormone production, siderophore production, exhibiting antifungal activity, stimulating production of volatile organic compounds (VOCs), interference with pathogen toxin production, beneficial plant microorganism symbiosis (Gouda et al., 2018). In addition, the use of PGPR strains can serve as a useful tool to alleviate salinity stress in salt-sensitive plants (Bharti et al., 2014).

Although there are sufficient reports of the effect of PGPR on the growth and development of many plants, information on the effect of PGPR on the quality and production of ornamental plants is limited (Zulueta-Rodriguez et al., 2014; Arab et al., 2015; Parlakova Karagöz et al., 2016). In order to evaluate this situation, the results using of PGPR alone and bacteria formulations to improve the biological and physico-chemical properties of the soil and plant quality in ornamental plant cultivation have been extensively reviewed by Parlakova Karagöz et al. (2020). Additionally, the role of PGPR in the management of ornamental plant diseases was discussed and evaluated (Orbera et al., 2014; Zaidi et al., 2016). Generally, PGPR facilitates the growth of ornamental plants by providing essential nutrients (Abbasniayzare et al., 2012). It improves the quantity and quality of ornamental plants

such as French marigold flower, rosesby plants (Preethi et al., 1999), geranium (Mishra et al.,, 2010), tulip (Khan et al., 2009; Parlakova Karagöz & Dursun, 2019a), safroon (Parlakova Karagöz et al., 2016), bamboo (*Bambusa bamboo*) (Dhamangaonkar & Misra, 2009), *Eleusine coracana* and *Amaranthus paniculatus* (Pandey et al., 1999), *Rosa damascena* Mill (Tariq et al., 2016), *Camellia japonica* (Park et al., 2017), hyacinth (*Hyacinthus orientalis* L.) (Parlakova Karagöz et al., 2019a), poinsettia (*Euphorbia pulcherrima*) (Silva & Iveth, 2011; Zulueta-Rodriguez et al., 2014; Parlakova Karagöz, 2020), *Rosa canina* (Kınık, 2014), *Ficus benjamina* L., (Sezen et al., 2014).

The use of PGPR in combination with renewable resources and/or organic fertilizers to improve the biological and physico-chemical properties of the soil is also one of the methods used in plant cultivation. Organic fertilizers such as vermicompost, zeolite and leonardite are among these renewable resources. It has been determined that these renewable resources can be used together with the production of ornamental plants with PGPR. As a result, efforts are made to increase in product yield and quality (Baloach et al., 2014). Various research results show that the combinations of PGPR + AM fungi (Ramlakshmi & Bharathiraja, 2015), PGPR + endophytes, PGPR + vermicompost (Narayanagowda, 2003; Nazari et al., 2008; Pandey et al., 2017; Parlakova Karagöz et al., 2019b) can be used very effectively to increase in the flower quality and yield of ornamental plants. The aim of this study is to present a brief summary of both standard and novel findings obtained using PGPR and some other viable alternative

growing media components in ornamental plant cultivation based on a detailed literature review.

1. PGPR AND OTHER SOME VIABLE ALTERNATIVE MEDIA COMPONENT

Ensuring and maintaining vitality in the soil is carried out by the activities of soil microorganisms. Microorganisms in the soil by mineralizing the nutrients that are in the form that cannot be taken and transform them into the form that can be taken. For this reason, there is a parallel relationship between the biological activity of the soil and its productivity. It is stated that the criteria of biological activity (number of soil microorganisms, CO_2 production, and enzyme activity) and soil fertility criteria are the same (Colak, 1988). There is a great variety of microorganisms in the soil, ranging from antagonistic (Tzfira & Citovsky, 2007; Geiser et al., 2013) to mutualistic relationships (Lugtenberg & Kamilova, 2009), and they form biotic interactions with plants (Franklin et al., 2016). It has been reported that the most studied microorganisms in the plant-microorganism relationship are those that develop around the root and root. Because bacteria and fungi growing in this region are characterized in a way that can affect on plant growth and development positively or negatively (Lakshmanan et al., 2014). In addition, Paul & Clark (1996) stated that microorganisms in plant rhizospheres are generally found in areas closer to food. Generally, about 2-5% of microorganisms are PGPR (Siddikee et al., 2010). 15% of the root surface is covered with microbial populations of several bacterial species (Govindasamy et al., 2011). The diversity and

microbial abundance in the rhizosphere is greater than that of the soil. Pinton et al. (2007) stated that the number of microbial cells per soil in the rhizosphere is between 10^9 and 10^{12}. The presence of microorganisms in the rhizosphere is mainly due to the release of exudates from the roots and their chemical composition, which is their main function to feed the microorganisms (Lugtenberg & Bloemberg, 2004). The product of plant photosynthesis is secreted by the roots in the form of different sugars, which in turn are used by populations of microorganisms (Glick, 2014). The subsequent metabolic activities of these bacteria are the transport of mineral nutrients in the rhizosphere and their uptake by plant roots (Glick, 1995).

The presence of organic matter in the soil is needed for the continuity of microbial activities. Microorganisms meet their nutritional needs by breaking down organic matter, and plants benefit from decomposed minerals as a food source. Organic wastes of animal and vegetable origin are mixed into the soil / growing medium, and PGPR is added to the soil / growing medium to increase in the population of beneficial bacteria.

The effects of the PGPR may vary depending on the bacteria-plant combination, bacterial type and number, growth period, plant genotype, harvest date, soil type, vegetative parameters, organic matter amount, root secretions (Choudhary et al., 2019) and environmental conditions (Çakmakçı et al., 2006). Some types of bacteria also include mycorrhiza helper bacteria that help arbuscular mycorrhizal fungi (AMF) (Andrade et al., 1997; Moncada et al., 2020).

AMF act as bio-fertilizer. It facilitates the growth of the plant by increasing in the chlorophyll content (Demir, 2004), increasing in the nutrient intake (especially P) and providing tolerance to the plant against to different stresses (Tanwar et al., 2013). PGPR can be used with AMF to increase in the quality and yield of ornamental plants (Bianciotto & Bonfante, 2002). PGPR interact with the mycorrhizal fungi by adhering to fungal spores and hyphal structures, initiating spread and exposure to other microorganisms capable of symbiosis within the rhizosphere (Garbaye, 1994). There are reports proving that the application of commercial AM fungal-inoculants can improve plant growth and flowering performances of several ornamental (*Gazania rigens* (Sabatino et al., 2019), *Catalpa bungei* (Chen et al., 2020), *Hyacinths orientalis* (Xie & Wu, 2018), *Mimosa pudica* L. (Quan et al., 2021)).

Vermicompost, the use of which is increasing day by day in sustainable agriculture, is a material produced by the digestion of organic material by earthworms, which is reported to have more positive effects on plant growth, soil improvement, plant health and the environment than normal compost (Fritz et al., 2012; Bellitürk et al., 2015; Emperor & Kumar, 2015). Vermicompost is a rich mix of micro and macro nutrient sources. 97% of the plant nutrients in vermicompost (P, N and K) is directly available form by the plant during growth (Barley, 1961). It contains plant growth promoting substances such as NAA, gibberellins, cytokinins. It also increases in the yield of fertilizers added to the soil (Fritz et al., 2012). Vermicompost can be produced from many

agricultural (vegetable waste), domestic, industrial and farm origin (cattle manure) wastes (Manyuchi et al., 2013). Vermicompost also acts as a chelating agent and improves plant yield and growth by providing nutrients in the available form, as well as regulating the availability of metabolic micronutrients such as zinc and iron to plants (Barley, 1961; Chaoui et al., 2003; Arancon et al., 2004; Küçükyumuk et al., 2014; Ceritoğlu et al., 2019). It is also cost effective. The effects of the use of vermicompost in the cultivation of ornamental plants have been revealed as a result of many studies. Vermicomposts were reported to be an appropriate substrate for growing China aster (Balaji et al., 2006), marigold (Shadanpour et al., 2011; Heydari et al., 2017), gladiolus as cut flower (Gangadharan & Gopinath, 2000), gerbera (Narayanagowda, 2003), busy Lizzy (Asciutto et al., 2006), dahlia (Warade et al., 2007), cornflower (Bachman & Metzger, 2008), petunia and pelargonium (Alvarez et al., 2019) and chrysanthemum (Hidalgo & Harkess, 2002; Padamanabhan, 2021).

Zeolite is a chemical mineral in the content of hydrated aluminum silicate. Zeolites are special diagenized pyroclastic rocks with distinctive properties (high and selective cation exchange capacity, high water retention, balanced water uptake and release, ion exchange, nutrient exchange, and ability to regulate acidity and air porosity) that justify their advantageous application in the field of agricultural and ornamental plants. In addition, zeolite is a slow-release fertilizer (Sand & Mumpton, 1978; Polat et al., 2004; Ozbahce et al., 2018; Dobrowolska & Żurawik, 2016). The use of zeolites in floriculture

caused an increase in plant height, total inflorescences, number of buds and flowers, and bulb size (tulip) (Prisa, 2019). It led to an earlier development of flowering in geranium (Passaglia et al., 1998; Passaglia & Poppi, 2005). The using of zeolites in growing media was reported to be an appropriate substrate for growing kamelya ve leucospermum (Prisa & Burchi, 2015), impatiens ve oleander (Prisa, 2019), diffenbachia ornamental plant (Karami et al., 2011; Mohammadi Torkashvand et al., 2013), sage (*Salvia officinalis* L.) (Mahmoud & Swaefy, 2020), cactus pear (*Opuntia Ficus-indica* L. Mill.) (Prisa, 2020), *Viola odorata* L. (Mohamed & Ghatas, 2016).

2. EFFECT OF PGPR AND OTHER SOME VIABLE ALTERNATIVE MEDIA COMPONENT ON ORNAMENTAL PLANTS

The use of environmental and sustainable ornamental plant production practices with renewable resources has attracted worldwide attention. Organic fertilizers such as vermicompost and leonardite are among these renewable resources. It has been determined that these renewable resources can be used together with the production of ornamental plants with PGPR. Research abstracts on these results were reviewed below.

Srivastava & Govil (2007) have evaluated the effects of bio fertilizers (phosphate solubilizing bacteria, *Azotobacter*, VA-mycorrhiza) and farm manure on flowering and growth of gladiolus. In general, vegetative and vegetative characters are significantly improved following the application of bio fertilizers over control. Among the bacterial cultures, *Azotobacter* had the maximum positive effect on vegetative growth, while phosphate solubilizing bacteria increased in

the quality of flower spikes to the highest level. Moreover, the treatment of corm with bio fertilizers increased in the total rhizosphere bacteria population and the maximum population was recorded for the treatment of *Azotobacter* relative to the control. Researchers have suggested that the enhanced character of gladiolus plants was likely due to the growth-promoting activities of the inoculated bacteria (Table 1).

Padmadevi et al. (2004) have been reported that the application of *Azospirillum* sp., phosphobacteria and vesicular arbuscular mycorrhizas improved flower characteristics (*Anthurium andreanum* Lind.) (Table 1).

Shubha (2006) has been stated that the maximum vegetative parameters, the floral characters, uptake of P and N were recorded in treatment vermicompost (12.5% N) + poultry manure (12.5% N) + 200 g of *Azospirillum* along with 75% recommended dose nitrogen/ha. The same treatment found to be early for flower bud initiation, 50% flowering and maximum flowering duration (Table 1).

It was determined that various plant growth parameters, mineral content and secondary metabolites of *Begonia malabarica* Lam. changed with the applications (*Glomus mosseae* and some PGPRs). Among all applications, inoculated plants with the 'microbial consortium' of *Bacillus coagulans* + *Trichoderma viride* + *Glomus mosseae* performed better than the other treatments or uninoculated control plants (Selvaraj et al., 2008) (Table 1).

Ashok & Anju (2011) evaluated the effect of two AM fungi (*A. laevis* and *Funneliformis mosseae*) together with *T.viride* and *P. fluorescens* on *Chrysanthemum* growth and flowering. Shoot height, flower number, total chlorophyll content and phosphorus uptake (both in root and shoot) were recorded in the highest trio (*F. mosseae* + *T. viride* +*A. laevis*) inoculation. The highest fresh and dry shoot weight and stomatal conductivity were found in plants inoculated with the combination of *F. mosseae* + *T. viride*. Single inoculation of *F. mosseae* maximally increased in leaf area while increasing in some growth parameters in the presence of *T. virideit*. It has been found to be a superior combination for flowering and growth of *Chrysanthemum* when applied with *F. mosseae*, *T. viride* and *A. laevis* (Table 1).

A potting trial was conducted to determine the effect of co-inoculation of AMF (*Glomus mosseae* and *Acaulospora laevis*), different doses of superphosphate (low, medium and high) and the phosphate dissolving bacterium (*Pseudomonas fluorescens)* on gerbera's flowering response and growth system. Among all applications, plants inoculated with mixture culture of *G. mosseae* + *P. fluorescens* + *A. laevis*, in the low concentration of superphosphate were found to have greater root biomass, root length, AM spores number, percent root colonization, flower number, phosphatase activity and phosphorus content. In addition, the maximum increase in shoot biomass and leaf area was detected in plants applied with combination of *G. mosseae* + *P. fluorescens* in a low concentration of superphosphate. This study provides a good opportunity for commercial gerbera growth and

development using effective strains of *P. fluorescens* and AM fungus (Kuldeep Yadav et al., 2013) (Table 1).

Vermicompost enriched with bio fertilizer (P solubilizer (*A. awamori* and *S. marcescens*), Zn-solubilizer (*A. niger*)) significantly increased in the growth characteristics of the plant, such as stem circumference and bio-volume index, plant fresh and dry weight in addition to plant height. It was also observed that the number of flowers and flower diameter per plant increased significantly in vermicompost-treated plants when compared to farm manure and vermicompost alone (Ashwin et al., 2013) (Table 1).

Kumari et al. (2014) investigated the effect of *Pseudomonas* sp. (PGPR) and *Glomus* sp. (mycorrhiza) and different P levels on chrysanthemum growth, quality and yield. The combined effect of PGPR and different P levels was found to be significant and maximum fresh plant weight, plant dry weight and plant height were recorded with 'PSB + 15 P g / m^2' treatment. The minimum number of days until the first flowering, the number of days for bud initiation, the longest peduncle, the maximum number of flowers per plant and the number of buds per plant were obtained from the same treatment (Table 1).

Ramlakshmi & Bharathiraja (2015) reported that marigold growth and yield increased significantly in inoculation of phosphobacteria (*Paenibacillus poly-myxa*), AM fungi (*G. fasciculatum*) with 75% P and 100% NK fertilizers, were followed by AM fungi + phosphobacteria and 50% P and 100% NK fertilizers. As a result of this study, co-administration of AM fungi and phosphobacteria could

help reduce the use of phosphate fertilizers by 25% in marigold production (Table 1).

As a result of another investigation studied in the graded dose of nitrogen and biofertilizer indicated that the application of *Azotobacter*+phosphate-solubilizing bacteria+75% N/ha was found better with respect to plant growth, the maximum number of fresh flowers, prolonged the duration of flowering and advanced the flowering of calendula (Singh et al., 2008) (Table 1).

Tagetes erecta L. was inoculated with *Bacillus subtilis* strain BEB-13 and/or *Glomus fasciculatum* Gerdemann & Trappe at sowing and transplanting time. *Glomus* and/or *Bacillus* treated plants produced 14–24% more inflorescences than untreated plants. Although the treated flowers had significantly higher fresh weight than controls, they did not differ in size. *Bacillus* improved yellow color and flower clarity but not xanthophyll content, and *Glomus* enhanced xanthophyll content but not color properties (Flores et al., 2007) (Table 1).

The biofertilizers that included the lignite based cultures of *Pseudomonas fluorescens, Pseudomonas striata, Azospirillum* and *Trichoderma viridae* were used in the research conducted to study the effect of biofertilizers on yield, growth, quality and nutrient content in Jasmine with different levels of chemical fertilizers. Application of biofertilizers along with 50 per cent NPK brought about results on par with 100 per cent NPK fertilizer with respect to floral characteristics, chlorophyll content. Stalk length, flower diameter and petal length were

increased due to 50% RDF+biofertilizers. Biofertilizer application improved the total microbial population in the rhizosphere. When compared to all other treatments, 50% RDF+biofertilizers treatment resulted in the highest colonization of P-soluiblizers, N_2 fixers, *P. fluorescens* and *T. viridae* in the rhizopshere of jasmine. About 10 per cent increase in flower yield was obtained from 50% RDF+biofertilizers treatment (Jayamma et al., 2008) (Table 1).

Effects of growth parameters on osteospermum (*Osteospermum hybrida* 'Passion Mix') of arbuscular mycorrhizal fungus (AMF) (*Glomus mossea* CA) and *Bacillus panthea* and *Psedomonas putida* rhizobacteria (PGPR) promoting plant growth in different irrigation conditions (field capacity, two and one third of field capacity) have been evaluated. AMF and PGPR were inoculated as single or mixed. The results showed that plants inoculated with PGPR and mycorrhizal had better nutritional conditions than uninoculated plants and there was a synergistic effect between AMF and PGPR. PGPR has been determined to be as effective as AMF in alleviating the negative effects of drought stress. Applied microorganisms are more effective in improving plant growth parameters in 70% of field capacity. The effect of these microorganisms decreased when the field capacity was 40%. The results revealed that AMF and PGPR were utilized and that applying an optimized irrigation regime could be effective in increasing in the yield of *Osteospermum* (Azizollah et al., 2016) (Table 1).

Effects of the applications planned as A: PGPB formulation, B: Not autoclaved vermicompost, C: Autoclaved vermicompost, D: Not

autoclaved vermicompost + PGPBs, E: Autoclaved vermicompost + PGPBs, F: Control (untreated bacteria and vermicompost) on plant growth and development parameters of *Gladiolus* were tested in the research. A treatment was increase in 24.55% in plant height in gladiolus. The earliest flowering time was determined in E application. The same application increased in the corm diameter by 17.41% and the number of corm and cormel by 151.83% when compared to the F application. Autoclaved vermicompost may be a good choice in *Gladiolus* cultivation, but one conclusion of the study is that it should be enriched with PGPB (Parlakova Karagöz et al., 2019b) (Table 1).

Table 1: Effect of PGPR and Other Some Viable Alternative Media Component and Organic Substrates on Ornamental Plants

Ornamental plant material	Botanical name	Inoculant PGPR	Alternative component	Comments	References
Anthurium	*Anthurium andreanum* Lind.	*Azospirillum* sp.	Vesicular arbuscular mycorrhizas	Flowering characters	Padmadevi et al., (2004)
Marigold	*Tagetes erecta*. L	*Azospirillum spp. Phosphate solubilising bacteria (PSB)*	poultry manure, vermicompost	Plant growth parameters, N and P uptake, and flower yield	Shubha, (2006)
Gladiolus	*Gladiolus grandiflorus* Ness	PSB, *Azotobacter*	AM fungi and farm manure	Growth and flowering characters, total rhizosphere bacteria population	Srivastava & Govil, (2007)
Marigold	*Tagetes erecta* L.	*Bacillus subtilis*	*Glomus facsiculatum* (VAM)	Total inflorescence production, flower fresh weight, accelerated flower maturity, flower quality	Flores et al., (2007)

Calendula	*Calendula officinalis* L.	*Azotobacter*, PSB	FYM	Plant height, diameter of main stem, number of leaves, number of branches and flower yield	Singh et al., (2008)
Jasmine	*Jasminum auriculatum*	Mixture of *Azospirillum*, *Pseudomonas striata* and *Pseudomonas fluorescens*	*Trichoderma viridae*, FYM	Growth and flower quality characteristics and chlorophyll content	Jayamma et al., (2008)
Begonia	*Begonia malabarica* Lam.	*Bacillus coagulans*,	Arbuscular mycorrhizal fungi, *Glomus mosseae*, *Trichoderma viride*	Growth, biomass, nutrient contents of secondary metabolites	Selvaraj et al., (2008)
Chrysanthemum	*Chrysanthemum indicum*	*T.viride* and *P. fluorescens*	Two AM fungi (*A. laevis* and *Funneliformis mosseae*)	Growth and flowering parameters	Ashok & Anju, (2011)
Barberton Daisy	*Gerbera jamesonii*	*Pseudomonas fluorescens*	*Acaulospora laevis*, *Glomus mosseae*	*Gerbera*'s flowering response and growth system	Kuldeep Yadav et al., (2013)
Marigold	*Calendula officinalis*	*S. marcescens*, *A. awamori*, *A. niger*	Vermicompost	Growth and flower characteristics	Ashwin et al., (2013)
Chrysanthemum	*Chrysanthemum indicum*	PGPR (*Pseudomonas* sp.)	Mycorrhiza (*Glomus* sp.)	Growth, yield and quality characteristics	Kumari et al., (2014)
Marigold	*Calendula officinalis*	*Paenibacillus poly-myxa*)	AM fungi (*G. fasciculatum*)	Growth and yield	Ramlakshmi & Bharathiraja, (2015)
Osteospermum	*Osteospermum hybrida* 'Passion Mix'	*Bacillus panthea* and *Psedomonas putida* rhizobacteria	Arbuscular mycorrhizal fungus (*Glomus mossea* CA)	Growth and yield parameters	Azizollah et al (2016)

Gladiolus	*Gladiolus grandiflorus* L. 'Red Beauty'	*Bacillus megaterium* RK-1978, *Bacillus subtilis* RK-1977, *Pseudomonas fluorescens* RK-1979	Vermicompost	Plant growth and development parameters	Parlakova Karagöz et al., (2019b)
Marigold	*Calendula officinalis* Linn.	*Pseudomonas fluorescens*,fungi *Azotobactore chroococcum*	Mycorrhiza	Antioxidant capacity and some morphophysiological traits	Hasan et al., (2020)
Ranunculus	*Ranunculus asiaticus*	Chabazite Chabasite, enriched withzeolite PGPR		The plant height,leaves number, the vegetative and root weight, and flowers number and diameter the chlorophyll content	Domenico, (2020)

FYM: Farm yard manure

This research was carried out in greenhouse conditions to investigate the effect of bacteria and mycorrhizal fungi promoting plant growth under drought stress conditions for *Calendula officinalis* Linn. The use of 8 levels of bio fertilizers (including different combinations of *Pseudomonas, Azotobacter* and Mycorrhiza fungi) and drought stress at two levels (100% and 50% FC) were factors of the trial. As a result, plant height, leaf number, flower number, flower diameter, shoot weight and root weight, side branch number, chlorophyll index and relative water content decreased with the decrease of field capacity from 100% to 50%. Using *Pseudomonas fluorescens* alone or in combination with mycorrhizal fungi has also been found to improve growth characteristics such as leaf number, flower number, flower diameter, number of lateral shoot and vegetative index under stress

conditions (50% FC). In the application of *Pseudomonas fluorescens* under 100% FC, which is 77% higher than the control application (100% field capacity bio-fertilization was not used), the flower number is 18.50. The highest chlorophyll index was obtained from the simultaneous application of Mycorrhiza and *Azotobacter chroococcum* below 50% of the field capacity. It was concluded that the application of *Pseudomonas fluorescens* in soil alone or in combination with mycorrhiza fungi could improve plant growth under drought stress and increase in plant productivity under drought stress (Hasan et al., 2020) (Table 1).

Five application groups were established to evaluate the possibility of optimizing fertilizer use on *Ranunculus asiaticus* by adding chabasite with PGPR for the substrate: 1) group without zeolites, irrigated with water and substrate previously fertilized; 2) group with natural chabazite and 100% fertilised substrate; 3) group with chabazite enriched with PGPR and 100% fertilised substrate; 4) group with natural chabazite and 50% fertilised substrate; 5) group with chabazite enriched with PGPR and 50% fertilised substrate.

All plants treated with chabasite and chabasite enriched with PGPR showed a significant increase in the analyzed agronomic properties compared to the untreated control. The results show that microorganisms can improve the performance of the zeolitite, possibly increasing in the efficiency of the nutrient and water absorption by the roots (Domenico, 2020) (Table 1; Figure 1).

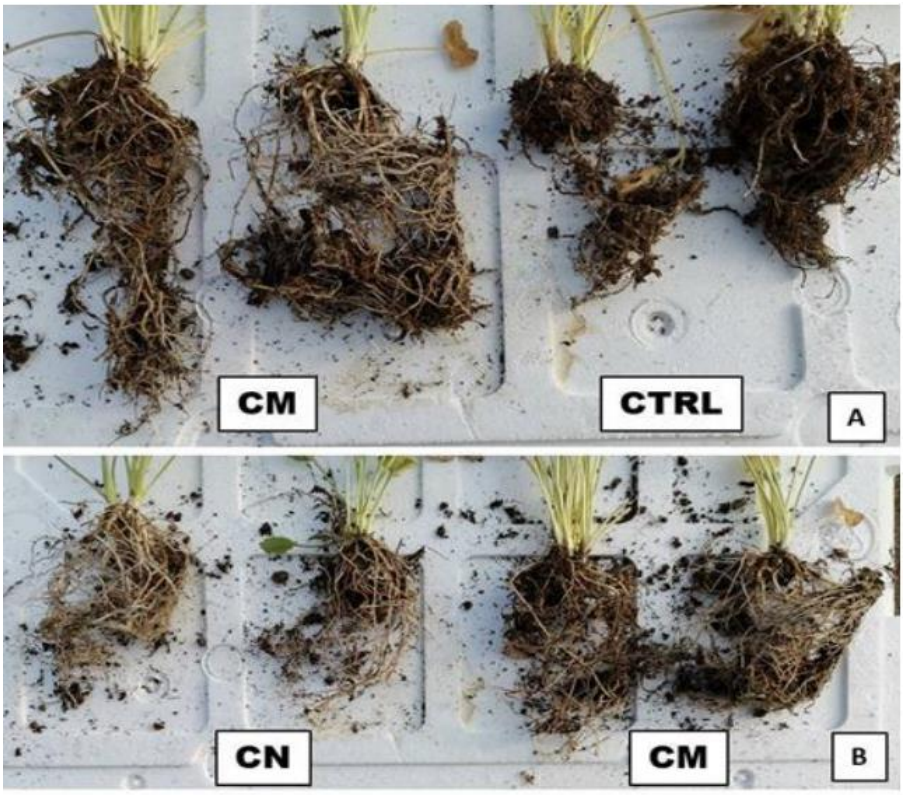

Figure 1: Effect of Zeolitites Containing PGPR on Roots Growth of *Ranunculus asiaticus* (CTRL: Control; CM: Chabazite Enriched with PGPR; CN Natural Chabazite) (Prisa, 2020)

CONCLUSION

It is possible to provide the nutrient needs in long-cycle of ornamental plant with the agronomic and physiological quality by using with some viable alternative media component and organic substrates and as an organic nutrient solution in fertigation combined with the application of PGPR. Based on the limited research results on this subject, it has been demonstrated that with the use of these, it is possible to achieve a reduction of up to 50% in the amount of fertilizer used for the growing

medium, and to provide aesthetic properties close to the plants grown in the growing medium with full fertilizer. However, the application of organic substrate and some viable alternative media components to the soil together with PGPRs may vary according to the substrate and soil properties such as bacteria-plant combination, bacteria type and number, growth period, plant genotype, vegetative parameters, organic matter amount, root secretions. Another conclusion that can be put forward as a result of this review is the result of further investigations are needed to determine effects on different ornamental plants of different PGPR strains, different viable alternative media component and organic substrates. Selection of bacteria and determination correct alternative media component may contribute to the concept of floriculture application in agriculture.

REFERENCES

Abbasniayzare, S.K., Sedaghathoor, S., & Dahkaei, M.N.P. (2012). Effect of biofertilizer application on growth parameters of *Spathiphyllum illusion*. Am Eurasian J Agric Environ Sci, 12: 669–673.

Alvarez, J.M., Pasian, C., Lal, R., López, R., & Fernández, M. (2019). Vermicompost and biochar substrates can reduce nutrients leachates on containerized ornamental plant production. Horticultura Brasileira, 37: 47-53.

Andrade, G., Mihara, K.L., Linderman, R.G., & Bethlenfalvay, G.J. (1997). Bacteria from rhizosphere and hyphosphere soils of different arbuscular-mycorrhizal fungi. Plant and Soil, 192(1): 71-79.

Arab, A., Zamani, G.R., Sayyari, M.H., & Asili, J. (2015). Effects of chemical and biological fertilizers on morpho-physiological traits of marigold (*Calendula officinalis* L.). Eur J Med Chem, 8(1): 60-68.

Arancon, N.Q., Edwards, C.A., Bierman, P., Welch, C., & Metzger, J.D. (2004). The influence of vermicompost applications to strawberries on growth and yield. Bio Resource Technology 93: 145–153.

Asciutto, K., Rivera, M.C., Wright, E.R., Morısigue, D., & López, M.V. (2006). Effect of vermicompost on the growth and health of *Impatiens wallerana*. International Journal of Experimental Botany, 75: 115-123.

Ashok, A. & Anju, T. (2011). Efficacy of bioinoculants, plant growth regulators and nutrients in prolonging vase life of *Chrysanthemum indicum* L. American-Eurasian Journal of Agricultural & Environmental Sciences, 11(4): 593-599.

Ashwin, R., Bagyaraj, D.J., & Kale, R.D. (2013). Response of marigold tobio-fertilizer enriched vermicompost. Soil Biol Ecol, 33: 160–166.

Azizollah, K.M., Mohammadreza, T., Farrokhi Forough, Z., & Farhad, R. (2016). Effects of arbuscular mycorrhizal fungus and plant growth promoting rhizobacteria (PGPR) under drought stress on growth of ornamental *Osteospermum* (*Osteospermum hybrida* 'Passion Mix'). Iranıan Journal of Hortıcultural Scıences, 47: 177-191.

Bachman, G.R. & Metzger, J.D. (2008). Growth of bedding plants in commercial potting substrate amended with vermicompost. Bioresource Technology, 99(8): 3155-3161.

Balaji, S., Kulkarni, M., Reddy, B.S., Patil, B.C., & Divakara, A. (2006). Influence of vermicompost and in situ vermiculture on the quality attributes and saleable yield in China aster. Scientific Horticulture, 10: 217-221.

Baloach, N., Yousaf, M., Akhter, W.P., Fahad, S., Ullah, B., Qadir, G., & Ahmed, Z.I. (2014). Integrated effect of phosphate solubilizing bacteria and humic acid on physiomorphic attributes of maize. Int J Curr Microbiol Appl Sci, 3: 549–554.

Barley, K.P. (1961). Plant nutrition levels of vermicast. Advances in Agronomy, 13: 251.

Bellitürk, K., Shrestha, P., & Görres, J.H. (2015). The importance of phytoremediation of heavy metal contaminated soil using vermicompost for sustainable agriculture. J Rice Res 3: e114. doi: 10.4172/2375-4338.1000e114.

Bharti, N., Barnawal, D., Awasthi, A., Yadav, A., & Kalra, A. (2014). Plant growth promoting rhizobacteria alleviate salinity induced negative effects on growth, oil content and physiological status in *Mentha arvensis*. Acta Physiologiae Plantarum, 36(1): 45-60.

Bianciotto, V. & Bonfante, P. (2002). Arbuscular mycorrhizal fungi: A specialised niche for rhizospheric and endocellular bacteria. Antonie van Leeuwenhoek, 81(1-4): 365-371.

Bozkurt, Y., Zeybek, Z., & Aşkın, R. (2020). Covid-19 pandemic: Psychological effects and therapeutic interventions. Istanbul Commerce University Journal of Social Sciences Covid-19 Social Sciences Special Issue, 19(37): 304-318.

Çakmakçı, R., Dönmez, F., Aydın A., & Şahin, F. (2006). Growth promotion of plants by plant growth-promoting rhizobacteria under greenhouse and two different field soil conditions. Soil Biol Biochem, 38: 1482-1487.

Ceritoğlu, M., Şahin, S., & Erman, M. (2019). Vermicompost production technique and materials used in production. Turk J Agric Res, 6(2): 230-236.

Chaoui, H.I., Zibilske L.M., & Ohno, T., (2003). Effects of earth worm casts and compost onsoil microbial activity and plant nutrient availability. Soil Biology and Biochemistry, 35: 295-302.

Chen, W., Meng, P., Feng, H., & Wang, C. (2020). Effects of arbuscular mycorrhizal fungi on growth and physiological performance of *Catalpa bungei* CA Mey. under drought stress. Forests, 11(10): 1117.

Choudhary, M., Meena, V.S., Yadav, R.P., Parihar, M., Pattanayak, A., Panday, S.C., Mishra, P.K., Bisht, J.K., Yadav, M.R., Nogia, M., Samal, S.K., Ghasal, P.C., Choudhary, J., & Choudhary, M. (2019). Does PGPR and Mycorrhizae Enhance Nutrient Use Efficiency and Efficacy in Relation to Crop Productivity? In Field Crops: Sustainable Management by PGPR (pp: 45-68). Springer, Cham. Sustainable Development and Biodiversity, 23. https://doi.org/10.1007/978-3-030-30926-8_3

Colak, A.K. (1988). Soil Microbiology and Biochemistry. Çukurova University Faculty of Agriculture Publications: 98, Adana.

Demir, S. (2004). Influence of arbuscular mycorrhiza on some physiological parameters of pepper. Turk J Biol, 28: 85–90.

Dhamangaonkar, S.N. & Misra, P. (2009). Effect of *Azotobacter chroococcum* (PGPR) on the growth of bamboo (*Bambusa bamboo*) and maize (*Zea mays*) plants. Biofrontiers, 1(1): 24-31.

Dobrowolska, A. & Żurawik, P. (2016). Zeolite as a component of substrate in cultivation of ornamental plants-*Catharanthus roseus* (L.) G. Don and *Gazania rigens* var. rigens (L.) Gaertn. Acta Scientiarum Polonorum-Hortorum Cultus, 15(2): 13-25.

Domenico, P. (2020). Optimised fertilisation with zeolitites containing Plant Growth Promoting Rhizobacteria (PGPR) in *Ranunculus asiaticus*. GSCBPS, 10(1): 096-102.

Emperor, G.N. & Kumar, K., (2015). Microbial population and activity on vermicompost of "*Eudrilus eugeniae*" and "*Eisenia fetida*" in different concentrations of tea waste with cow dung and kitchen waste mixture. International Journal of Current Microbiology and Applied Sciences, 4(10): 496-507.

Fasciglione, G., Casanovas, E.M., Quillehauquy, V., Yommi, A.K., Goni, M.G., Roura, S.I., & Barassi, C.A. (2015). *Azospirillum* inoculation effects on growth, product quality and storage life of lettuce plants grown under salt stress. Scientia Horticulturae, 195: 154-162.

Flores, A.C., Luna, A.A.E., & Portugal, V.O. (2007). Yield and quality enhancement of marigold flowers by inoculation with *Bacillus subtilis* and *Glomus fasciculatum*. J Sustain Agric, 31(1): 21-31.

Franklin, A.K., Sommers, P.N., Aslan, C.E., López, B.R., Bronstein, J.L., Bustamante, E., Búrquez, A., Medellín, R.A., & Marazzi, B. (2016). Plant biotic interactions in the Sonoran Desert: Current knowledge and future research perspectives. International Journal of Plant Sciences, 177(3): 217-234.

Fritz, J.I., Franke-White, I.H., Haindl, S., Insam, H., & Braun, R. (2012). Microbiological community analysis of vermicompost tea and its influence on the growth of vegetables and cereals. Canadaian Journal of Microbiology, 58: 836-847.

Gangadharan, G.D. & Gopinath, G. (2000). Effect of organic and inorganic fertilizers on growth, flowering and quality of *Gladiolus* cv. White Prosperity. Karnataka Journal of Agricultural Sciences, 11(3): 401-405.

Garbaye, J. (1994). Tansley review no. 76 helper bacteria: A new dimension to the mycorrhizal symbiosis. New phytologist, 128(2): 197-210.

Geiser, D.M., Aoki, T., Bacon, C.W., Baker, S.E., Bhattacharyya, M.K.,…& Zhang, N. (2013). One fungus, one name: defining the genus *Fusarium* in a Scientifically Robust Way that preserves longstanding use. Phytopathology, 103(5): 400-408.

Glick, B.R. (1995). The enhancement of plant growth by free-living bacteria. Can J Microbiol., 41: 109-117.

Glick, B.R. (2014). Bacteria with ACC deaminase can promote plant growth and help to feed the world. Microbiological Research, 169(1): 30-39.

Gouda, S., Kerry, R.G., Das, G., Paramithiotis, S., Shin, H.S., & Patra, J.K. (2018). Revitalization of plant growth promoting rhizobacteria for sustainable development in agriculture. Microbiol. Res, 206: 131-140.

Govindasamy, V., Senthilkumar, M., Magheshwaran, V., Kumar, U., Bose, P., Sharma, V., & Annapurna, K. (2011). *Bacillus* and *Paenibacillus* spp.: Potential PGPR for sustainable agriculture. In D. K. Maheshwari (Ed.), Plant growth and health promoting bacteria (pp. 333–364). Berlin: Springer-Verlag.

Hasan, M.S., Selahvarzi, Y., Nabati, J., & Aziz, M. (2020). Effect of mycorrhiza fungi and plant growth promoting rhizobacteria (PGPR) on antioxidant capacity and some morphophysiological traits of medicinal marigold (*Calendula officinalis* Linn.) under drought stress. Environ Stress Crop Sci, 13: 425-440.

Heydari, M., Daneshian Moghaddam, A.M., & Nourafcan, H. (2017). Effect of vermicompost and liquid seaweed fertilizer on morpho-physiological properties of marigold (*Calendula officinalis* L.). Journal of Crop Ecophysiology, 10(40 (4)): 891-906.

Hidalgo, P.R. & Harkess, R.L. (2002). Earthworm castings as a substrate amendment for *Chrysanthemum* production. Hortscience, 37(7): 1035-1039.

Jayamma, N., Jagadeesh, K.S., & Patil, V.S. (2008). Growth and flower yield of jasmine (*Jasminum auriculatum*) as influenced by biofertilizers and graded doses of chemical fertilizers. J. Ornam. Hortic, 1(4): 275-280.

Karami, A., Torkashvand, A.M., & Khomami, A.M. (2011). The effect of medium containing zeolite and nutrient solution on the growth of *Dieffenbachia amoena*. Annals of Biological Research, 2(6): 378-383.

Khan, F.U., Siddique, M.A.A., Khan, F.A. & Nazki, I.T. (2009). Effect of biofertilizers on growth, flower quality and bulb yield in tulip (*Tulipa gesneriana*). Ind J Agric Sci, 79: 248–251.

Kınık, E. (2014). Effects of auxin, mycorrhiza and plant growth promoting bacteria treatments on propagation of some woody ornamental plants by cutting. Msc, Ondokuz Mayıs University Graduate School of Natural and Applied Sciences, Samsun.

Küçükyumuk, Z., Gültekin, M., & Erdal, İ. (2014). Effects of vermicompost and mycorrhiza on plant growth and mineral nutrition in pepper. Journal of Süleyman Demirel University Faculty of Agriculture, 9(1): 51-58.

Kuldeep Yadav, K., Tanwar, A., & Aggarwal, A. (2013). Impact of arbuscular mycorrhizal fungi and *Pseudomonas fluorescens* with various levels of superphosphate on growth enhancement and flowering response of *Gerbera*. Journal of Ornamental Plants, 3(3): 161-170.

Kumari, A., Goyal, R.K., Sehrawat, S.K., Choudhary. M., & Sindhu, S.S. (2014). Growth, yield and quality of Chrysanthemum (*Chrysanthemum morifolium* Ramat.) cv. Dolly orange as influenced by biofertil-izers in combination with phosphorous. IJAEB, 7: 555–564.

Lakshmanan, V., Selvaraj, G., & Bais, H. (2014). Functional soil microbiome: Below ground solutions to an aboveground problem. Plant Physiology, 166(7): 689-700.

Lugtenberg, B. & Kamilova, F. (2009). Plant-Growth-Promoting Rhizobacteria. The Annual Review of Microbiology, 63(1): 541-556.

Lugtenberg, B.J. & Bloemberg, G.V. (2004). Life in the rhizosphere. In: *Pseudomonas*, Ed. JL Ramos. Kluwer Acad./Plenum. New York, USA. pp: 633.

Mahmoud, A.W.M. & Swaefy, H.M. (2020). Comparison between commercial and nano NPK in presence of nano zeolite on sage plant yield and its components under water stress. Agriculture, 66(1): 24-39.

Manyuchi, M.M., Phiri, A., Muredzi, P., & Chitambwe, T. (2013). Comparison of vermicompost and vermiwash biofertilizers from vermicomposting waste corn pulp. International Scholarly and Scientific Research & Innovation, 7(6): 389-392.

Mishra, R.K., Prakash, O., Alam, M., & Dikshit, A. (2010). Influence of plant growth promoting rhizobacteria (PGPR) on the productivity of *Pelargonium graveolens* L. Herit. Recent Res Sci Technol., 2: 53–57.

Mohamed, Y.F.Y. & Ghatas, Y.A.A. (2016). Effect of mineral, biofertilizer (EM) and zeolite on growth, flowering, yield and composition of volatile oil of *Viola odorata* L. plants. Journal of Horticultural Science & Ornamental Plants, 8(3): 140-148.

Mohammadi Torkashvand, A., Karami, A., & Mahboub Khomami, A. (2013). Zeolite: An appropriate alternative for peat in growth medium of *Diffenbachia* ornamental plant. Journal of Soil and Plant Interactions-Isfahan University of Technology, 4(2): 81-97.

Moncada, A., Miceli, A., & Vetrano, F. (2020). Use of plant growth-promoting rhizobacteria (PGPR) and organic fertilization for soilless cultivation of basil. Scientia Horticulturae, 275: 109733.

Narayanagowda, J.V. (2003). Effect of vermicompost and biofertilizers on growth and yield of gerbera (*Gerbera jamesonii* L.) cv. Local. National Symposium on Recent Advances in Indian Floriculture, Vellanikara, India, Kerala Agricultural University, pp: 19.

Nazari, F., Farahmand, H., Eshghi, S., Niki, M., & Eslamzade, M. (2008). The effect of different soil amendments on growth and flowering of African marigold (*Tagetes erecta* L.) 'Queen'. J Fruit Ornam, 16: 403-415.

Orbera, T.M., Serrat, M.J., & Ortega, E. (2014). Potential applications of *Bacillus subtilis* strain SR/B-16 for the control of phytopathogenic fungi in economically relevant crops. Biotecnol Apl, 31: 13–17.

Ozbahce, A., Tari, A.F., Gonulal, E., & Simsekli, N. (2018). Zeolite for enhancing yield and quality of potatoes cultivated under water deficit conditions. Potato Research, 61(5): 247–259.

Padamanabhan, V. (2021). Effect of vermicompost on growth and flowering of chrysanthemum. Annals of the Romanian Society for Cell Biology, 25(4): 5068-5077.

Padmadevi, K., Jawaharlal, M., & Vijayakumar, M. (2004). Effect of biofertilizers on floral characters and vase life of Anthurium (*Anthurium andreanum* Lind.) cv Temptation. South Ind Hort, 52: 228-231.

Pandey, A., Durgapal A., Joshi M., & Palni L.M.S. (1999). Influence of *Pseudomonas corrugata* inoculation on root colonization and growth promotion of two important hill crops. Microbiol Res, 154: 259-266.

Pandey, S.K., Kumari, S., Singh, D., Singh, V.K., & Prasad, V.M. (2017). Effect of biofertilizers and organic manures on plant growth, flowering and tuber production of dahlia (*Dahlia variabilis* L.) cv. SP Kamala. Int J Pure App, 5(2): 549-555.

Park, H.G., Lee, Y.S., Kim, K.Y., Park, Y.S., Park, K.H., Han, T.H., & Ahn, Y.S. (2017). Inoculation with *Bacillus licheniformis* MH48 promotes nutrient uptake in seedlings of the ornamental plant *Camellia japonica* grown in Korean reclaimed coastal lands. *원예과학기술지*, 35(1): 11-20.

Parlakova Karagöz, F. & Dursun, A. (2019a). Effects of nitrogen fixing and phosphate solubilizing bacteria on growth and bulbs production of tulip cultivars. Journal of Ege University Faculty of Agriculture, 56(2): 241-248.

Parlakova Karagoz, F. & Dursun, A. (2019b). A study of different bacterial formulations in increasing the nutrient content of bulb and leaf of tulips and grown soil samples. IJHSOP, 11(1): 52-65.

Parlakova Karagöz, F. (2020). Evaluation of the bacteria formulation different inoculum densities on growth and development of *Euphorbia pulcherrima*. *Folia* Hortic, 32(2): 179-188.

Parlakova Karagöz, F., Dursun, A., & Karagöz, H. (2020). A Review Evaluation of Plant Growth Promoting Rhizobacteria in Ornamental Plants Industry. (pp: 441-489), In: Ornamental Plants in Different Approaches, Çığ, A. (ed.), ISBN: 978-625-7687-07-2. İksad Publishing House, Ankara-Turkey, p. 528.

Parlakova Karagöz, F., Dursun, A., & Kotan, R. (2019a). Effects of rhizobacteria on plant development, quality of flowering and bulb mineral contents in *Hyacinthus orientalis* L. Alınteri Zirai Bilimler Dergisi, 34(1): 88-95.

Parlakova Karagöz, F., Dursun, A., Kotan, R., Ekinci, M., Yildirim, E., & Mohammadi, P. (2016). Assessment of the effects of some bacterial isolates and hormones on corm formation 400 and some plant properties in saffron (*Crocus sativus* L.). J AGR SCI, 22(4): 500-511.

Parlakova Karagöz, F., Dursun, A., Tekiner, N., Kul, R., & Kotan, R. (2019b). Efficacy of vermicompost and/or plant growth promoting bacteria on the plant growth and development in gladiolus. Ornam. Hortic, 25(2): 180-188.

Passaglia, E. & Poppi, S. (2005). Risparmio idrico e di fertilizzanti nella coltivazione di ortaggi e frutta in terreni ammendati con zeolitite a chabasite. Atti 3° Convegno AISSA "Il pianeta acqua nel continente agricoltura", Facoltà di Agraria dell'Università di Modena e Reggio Emilia, 6-7 Dicembre, pp: 109-110.

Passaglia, E., Marchi, E., & Manfredi, F. (1998). Zeoliti arricchite in NH_4 nella coltivazione in vaso di gerani (*Pelargonium zonale*). Flortecnica, novembre: 11-15.

Paul, E.A. & Clark, F.E. (1996). Soil microbiology and biochemistry. Second edition. Academic Press Inc. San Diego, California. USA. pp: 273.

Pinton, R., Varanini, Z., & Nannipieri, P. (2007). The rhizosphere: Biochemistry and organic substances at soil-plant interface. Second edition. CRC Press. Boca Raton, Florida, USA. pp: 472.

Polat, E., Karaca, M., Demir, H., & Onus, A.N. (2004). Use of natural zeolite (clinoptilolite) in agriculture. Journal of fruit and ornamental plant research, 12(1): 183-189.

Preethi, T.L., Pappiah, C.M., & Anbu, S. (1999). Studies on the effect of *Azospirillum* sp., nitrogen and ascorbic acid on the growth and flowering of Edward rose (*Rosa bourboniana* Desp.). J South Ind Hortic, 47: 106–110.

Prisa, D. & Burchi, G. (2015). The strength of chabasite (Italian). il Floricultore, 5-6: 40-44.

Prisa, D. (2019). Improvement quality of impatiens and oleander plants with chabazitic-zeolites. International Journal of Recent Scientific Research, 10(04): 31727-31730.

Prisa, D. (2020). Comparison between sterilized zeolite and natural zeolite in the Cactus Pear (*Opuntia Ficus-Indica* L. Mill.) growing. GSC Advanced Research and Reviews, 5(1): 007-014.

Quan, L., Zhang, J., Wei, Q., Wang, Y., Qin, C., Hu, F., ... & Xia, Y. (2021). Promotion of zinc tolerance, acquisition and translocation of phosphorus in *Mimosa pudica* L. mediated by arbuscular mycorrhizal fungi. Bulletin of Environmental Contamination and Toxicology, 106(3): 507-515.

Ramlakshmi, R. & Bharathiraja, S. (2015). AM fungi and phosphate solubilizing bacteria (*Paenibacillus polymyxa*) as a potential bioinoculant for marigold. Intern J Curr Res, 7: 12264–12266.

Sabatino, L., Fabio, D.A., Torta, L., Ferrara, G., & Iapichino, G. (2019). Effects of arbuscular mycorrhizal fungi on *Gazania rigens* pot plant cultivation in a mediterranean environment. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 47(1): 221-226.

Sand, L.B. & Mumpton, F.A. (1978). Natural Zeolites: Occurrence, Properties, Use. (No. CONF-760626-(Exc.)). Pergamon Press, Inc., Elmsford, NY.

Selvaraj, T., Rajeshkumar, S., Nisha, M.C., Wondimu, L., & Tesso, M. (2008). Effect of *Glomus mosseae* and plant growth promoting rhizomicroorganisms (PGPR's) on growth, nutrients and content of secondary metabolites in *Begonia malabarica* Lam. Maejo Int J Sci Technol, 2: 516–525.

Sezen, I., Kaymak, H.Ç., Aytatlı, B., Dönmez, M.F., & Ercişli, S. (2014). Inoculations with plant growth promoting rhizobacteria (PGPR) stimulate adventitious root formation on semi-hardwood stem cuttings of *Ficus benjamina* L. Propagation of Ornamental Plants, 14(4): 152-157.

Shadanpour, F., Torkashvand, A.M., & Majd, K.H. (2011). The effect of cow manure vermicompost as the planting medium on the growth of marigold. Annuals of Biological Research, 2(6): 109-115.

Shubha, B.M. (2006). Integrated Nutrient Management for Growth, Flowering, and Xanthophyll Yield of Marigold (*Tagetes erecta.* L.). Doctoral dissertation, UAS, Dharwad.

Siddikee, M.A., Chauhan, P.S., Anandham, R., Han, G.H., & Sa, T. (2010). Isolation, characterization, and use for plant growth promotion under salt stress, of ACC deaminase producing halotolerant bacteria derived from coastal soil. Journal of Microbiology and Biotechnology, 20: 1577–1584.

Silva, N. & Iveth, M. (2011). Potencial de rizobacterias *Pseudomonas putida* como biofertilizantes para el crecimiento de plantas de Nochebuena (*Euphorbia pulcherrima* L.). Universidad Veracruzana (México), Tesis.

Singh, N., Pandey, P., Dubey, R.C., & Maheshwari, D.K. (2008). Biological control of root rot fungus *Macrophomina phaseolina* and growth enhancement of *Pinus roxburghii* (Sarg.) by rhizosphere competent *Bacillus subtilis* BN1. World J Microbiol Biotechnol, 24: 1669-1679.

Srivastava, R. & Govil, M. (2007). Influence of biofertilizers on growth and flowering in *Gladiolus* cv. American Beauty. Acta Hortic (ISHS), 742: 183-188.

Tanwar, A., Yadav, K., Prasad, K., & Aggarwal, A. (2013), Biological amendments of growth, nutritional quality and yield of celery. Int J Veg Sci, 19: 228–239.

Tariq, U., Riaz, A., Jaskani, M.J., & Zahir, Z.A. (2016). Screening of PGPR isolates for plant growth promotion of *Rosa damascena*. International Journal of Agriculture and Biology, 18(5): 997-1003.

Torkashvand, M. (2009). General Pedology. Islamic Azad University, Iran, pp: 288.

Tzfira, T. & Citovsky, V. (2007). Agrobacterium: From biology to biotechnology. Springer Science & Business Media. New York. USA. pp: 750.

Warade, A.P., Gollıwar, V.J., Chopde, N., Lanje, P.W., & Thakre, S.A. (2007). Effect of organic manures and bio-fertilizers on growth, flowering and yield of *Dahlia*. Journal of Soils & Crops, 17(2): 354-357.

Xie, M.M. & Wu, Q.S. (2018). Arbuscular mycorrhizal fungi regulate flowering of *Hyacinths orientalis* L. Anna Marie. Emirates Journal of Food and Agriculture, 30(2): 144-149.

Younis, A., Riaz, A., Ikram, S., Nawaz, T., Hameed, M., Fatima, S., Batoo, l. R., & Ahmad, F. (2013). Salinity-induced structural and functional changes in three cultivars of *Alternanthra bettzikiana* (Regel) G. Nicholson. Turk J Agric For, 37: 674–687.

Zaidi, A., Khan, M. S., Ahmad, E., Saif, S., Rizvi, A., & Shahid, M. (2016). Growth stimulation and management of diseases of ornamental plants using phosphate solubilizing microorganisms: current perspective. Acta Physiologiae Plantarum, 38(5): 117.

Zulueta-Rodriguez, R., Cordoba-Matson, M.V., Hernandez-Montiel, L.G., Murillo-Amador B., Rueda-Puente, E., & Lara, L. (2014). Effect of *Pseudomonas putida* on growth and anthocyanin pigment in two poinsettia (*Euphorbia pulcherrima*) cultivars. The 19 Scientific World Journal, Volume 2014, Article ID 810192, 6 pages. http://dx.doi.org/10.1155/2014/810192

CHAPTER VIII

PHYTOREMEDIATION OF HEAVY METAL POLLUTION BY ORNAMENTALS AND MOLECULAR MECHANISMS OF THE METAL HYPERACCUMULATION

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INTRODUCTION

The threat of overpopulation is one of the most important problems that affect the future of the world in an alarming way. The 20th century saw the largest increase in world population in human history. The world population grows by 1.2 percent every year, increasing by approximately 74 million people. When we consider that the global population has doubled in less than 50 years and the UN's medium-scale prediction expecting that the 7 billion population would reach at least 9 billion by 2050, we perceive the seriousness of the situation better. Moreover, population growth is not evenly distributed throughout the world (Baus, 2017; URL-1).

Since the beginning of the industrial revolution, because of the reasons suc as industrialization, technological advances, wars, irregular urbanization and the increase in people's consumption desire, natural resources are rapidly depleted, climate changes occured, and as a result, human beings are faced with many problems, especially food and water deficiency. All these developments have made the importance of the environmental pollution problem felt much more (Babaoğlu Aydaş, 2008).

Heavy metals have an important place among soil pollutants. Contamination of soils, waters and atmosphere with heavy metals can be as a result of industrial activities, military operations, nuclear power stations, vehicle exhausts, electroplating, burning of fossil fuels, mining, mine disposal, application of sewage sludge to the soil, manure,

chemical agricultural practices such as fertilizers and pesticides, herbicides and inappropriate municipal wastes and waste disposal. It can also occur when rocks containing metal are dissolved and transported to water and soil environment for various reasons such as volcanic activities, erosion or weathering (Timothy et al., 2019).

Every day, the fascinating diversity of plants around us gives us a different pleasure. Although this is very related to our aesthetic perception, is also related to the fact that human beings have met their basic needs such as nutrition, shelter, heating, covering and treatment since the first day they emerged in order to survive in the world, thanks to plants. Recent researches on model plants has a great impact on the increase in our basic molecular and functional understanding of plants. Our experience in bioinformatics, molecular genetics, omics, metabolic engineering and nanotechnology and thus in plant biology helps us to better understand phylogenetic relationships and to use natural or transgenic plants in a more functional way. In this way, it is possible for human beings to produce solutions to many problems that they have created or encountered in the world (Kramer, 2010).

Phytoremediation is an easthetical, economical and ecologically sensitive methot that can be used for the reclamation of contaminated soil (metalloids, xenobiotics, explosives, polyaromatic hydrocarbons PAHs, petroleum hydrocarbons, pesticides, pharmacutical/cosmetic products and nanoparticles) without disturbing the soil fertility and biodiversity (Cristaldi et al., 2017; Ashraf et al., 2019)

1. HEAVY METALS

Metals are characterized as heavy metals because of their high atomic weight or their high density. Nowadays, the expression ‘heavy metal’ is one of the terms commonly used in scientific publications on metal toxicity or metal pollution and describes metallic chemical elements and metalloids which are toxic to the environment and humans (Briffa et al., 2020).

In low concentrations, some trace elements such as, Cr, Cu, Ni, Mo, Zn and Se, are necessary for the healthy metabolism and reproduction of microorganisms, plants, animals, containing humans. On the other hand, at high concentrations, these basic elements can be toxic. Some trace elements such as As, Cd, Pb, Hg are not essential, and even their very low concentrations in the environment can be toxic for both plants and animals (Prasad, 2004).

Excessive proportions of metals can be harmful to the organism and plants by disrupting the metabolic mechanisms of vital organs and glands. They also prevent the biological functions of vital nutritional minerals by removing from their original places (Timothy et al., 2019).

Since heavy metal pollution in the soil also reduces the biodegradability of organic pollutants, it further increases the effect of their polluting of the environment in this way. Metals in the soil pose a great danger to the entire biosphere. The pathways for metals to enter the food chain are through direct ingestion and absorption by plants, so they can be detrimental to both the plant and the food chain that eats the plant. It

changes the soil's properties such as porosity, pH, natural chemistry, and colour, deteriorating the soil quality and also polluting the water. (Briffa et al., 2020).

Many techniques have been developed to remove heavy metal pollution from soil, water and sediments including, membrane filtration adsorption, physical encapsulation, coagulation-flocculation, ion exchange, chemical precipitation, floatation, soil excavation, virtification, landfilling. Most physical and chemical heavy metal remediation technologies destroy the surrounding ecosystems, require the processing of large quantities of sludge and is very expensive. Also, factors such as the complex physical, chemical and biological properties of contaminated soil, and limited information on the behavior and relationships of pollutants in the soil environment are the other challenging aspects (Lambert et al., 2000; URL-2).

2. PHYTOEXTRACTION OF HEAVY METAL POLLUTED SITES BY ORNAMENTALS

Phytoextraction is a technique that allows metal pollutants to be removed from the soil by absorption of the plant roots and transported by the plant to the tissues and then to be deposited in its harvestable organs. After each harvest, the amount of pollutants in the soil will decrease slightly. Natural or genetically modified plants are used to carry out this process (Cristaldi, 2017; Ashraf, 2019).

Plant species are divided into two groups in terms of their capacity to remove heavy metals from the soil and the strategic mechanisms they

follow in this process: Excluders prevent metal accumulation in cells and thus can tolerate heavy metals in soil up to threshold concentration. This way of exclusion is achieved either by blocking the uptake in the roots or by active efflux pumps (Leitenmaier & Küpper, 2013). "Hyperaccumulators", on the other hand, transport, accumulate and tolerate metals at significant levels in their shoots without harming plant growth and vital physiological mechanisms of the plant. To be able to say that a plant is ideal for phytoextraction, it must have both a high biomass production and accumulation capacity of target metals in harvestable (aboveground) plant organs because it will not be applicable to remove metals from the soil by harvesting root biomass. (Pajevic et al., 2016). Metal hperaccumulator plants have the feature of accumulating above 100 mg kg^{-1} dry weight of As and Cd, more than 1000 mg kg^{-1} dry weight of Cu, Ni, Co, Pb, and over 10,000 mg kg^{-1} dry weight of Mn and Zn in aerial organs (Baker & Brooks, 1989). Hyperaccumulation of metals is an evolutionary adaptation of plants in disadvantageous habitats with high heavy metal contents such as ultrabasic rocks and serpentine soils (Babaoğlu Aydaş, 2008; Mahar et al., 2016).

In polluted areas, hyperaccumulator plants can only be used for remediation; alternatively, excluders may be added for commercial purposes, especially the use of relatively safe plants such as pharmaceutical, ornamental, or industrial plants, if not consumed, are the examples of safe plant management of contaminated areas. (Antoniadis et al., 2017). Studies on metal accumulation in plants will

also cause a progress in biofortification technologies, or in improving the nutrient efficiency of crops (Kramer, 2010).

Ornamental plants are grown for decorative purposes in various shapes, sizes and colors and have the desired garden characteristics. They also form landscapes by adapting to a wide variety of climatic conditions. Common ornamental features include their fruits, leaves, flowers, scent, overall foliage texture, stems and bark, and aesthetic form. It can be observed that ornamental plants generally consist of various plant species from herbaceous to woody, from low to high and from water to land (Liu et al., 2017). The ornamental values of plants may vary according to the different tastes and traditions of each country (Capuana, 2019). The use of ornamental plants as an art to shape gardens and as an object of beauty, as well as to express philosophical and religious beliefs, is as old as the existence of civilizations. Ornamental plants became an important industry and a tourism resource in the world at the beginning of the 20th century (Mikail & Çığ, 2020).

Unlike other plant species used for phytoremediation, some ornamental plants can both beautify the environment and remediate the polluted soils, especially in urban areas. Thanks to the accumulation of pollutants in ornamental plants, the risks of joining the food chain are also reduced, so they do not pose a threat to human health. The use of ornamental plants in phytoremediation applications makes great contributions both economically and ecologically. Because of the short growth cycle of herbaceous ornamentals, the plant's response to stress can be observed and recorded during the complete growing season in a

greenhouse. In this way, the use of the plant in field trials will be much more effective and the results will be predictable. Taking advantage of the enormous diversity and abundance of the many available ornamental plants will facilitate the screening of potential local ornamental plants for phytormediation of heavy metal contaminated environments. The biomass of ornamental plants obtained after such activities could be used or sold as a raw material in the production of silk pot plans, cut flowers, , perfumes, air fresheners, essential oils, metal phytoming and silk production. Terrestrial and aquatic ornamental plants could be used for remediating both soil and water. (Liu et al., 2017; Lajayer et al., 2019; Capuana, 2019; Khan et al., 2021).

Some examples of ornamental plants used in phytoextraction and the metals they extracted efficiently are; *Mirabilis jalapa* and *Tagetes erecta*, Cr, (Miao & Yan, 2013) and Pb (Madanan et al., 2021); *Mirabilis jalapa*, Cd (Yu & Zhou, 2009); *Chlorophytum comosum*, Pb (Wang et al., 2011) and Cd, (Wang et al., 2012); *Melastoma malabathricum*, Pb, As (Selamat et al., 2014); *Chrysanthemum indicum*, Pb, (Mani et al., 2015); *Helianthus annuus*, *Hydrangea paniculata*, Cu and Pb, (Forte & Mutiti, 2017); *Celosia cristata pyramidalis*, Pb (Cui et al., 2013); *Celosia cristata*, *Helianthus annuus*, *Tagetes patula* Cr, Mn, Fe, Cu, Zn, Pb (Chatterjee et al., 2012); *Lonicera japonica*, Cd, (Liu et al., 2009); *Alyssum murale*, *Leptoplax emarginata*, Ni (Pardo et al., 2018); *Calendula officinalis*, Cu

(Goswami & Das, 2016); *Iris hexagona*, Cd, (Han et al., 2015). *Calendula officinalis*, *Althaea rosea*, Cd, Pb, (Liu et al., 2008).

Madanan et al. (2021) determined the Cd, Zn, Pb, hyperaccumulation capacity of *Tagetes erecta* L. ornamental plant. They evaluated the metal concentrations in the root and aerial parts of the plant depending on the heavy metal concentration in the soil. Heavy metal uptake was highest for Cd (346 mg kg^{-1}) when the spiked cadmium concentration of the soil was 160 mg kg^{-1}. Tagetes erecta was a good phytoextractor and accumulator of cadmium. Plant was a hypertolerant of Pb (18.3 mg kg^{-1}) and a hyperaccumulator of Zn (256 mg kg^{-1}).

In the study of Cui et al. (2013), when *Celosia cristata pyramidalis* was grown in soil containing 5000 mg kg^{-1} Pb, the maximal mesured shoot Pb concentration exceeded 1000 mg kg^{-1} which is the thresold value of a Pb hyperaccumulator.

Wang et al. (2012) determined the influence of Cd stress on growth, physiological indices and Cd accumulation in *Chlorophytum comosum* with pot experiments. The tolerance index (TI) of *C. comosum* were all above 100 in soil Cd concentration of 100 mg kg^{-1}. The cadmium in root and aboveground parts of *C. comosum* was 1,522 and 865·5 mg kg^{-1}, respectively, in cadmium concentration of soil up to 200 mg kg^{-1}. They suggested that *C. comosum* could have a very effective application value in the cultivation of soils contaminated with cadmium due to its advantages such as high cadmium tolerance and accumulation property with ornamental value.

Goswami & Das (2016) investigated *Calendula officinalis* for copper remediation. The results exhibited that this plant had high Cu tolerance of up to 400 mg kg^{-1} which is well above the range determined as phytotoxic for non-hyperaccumulatory plants. It continued to grow normally in soils at all doses (150-400 mg kg^{-1}) and did not show any external signs of phytotoxicity. The plant showed a high tolerance (up to 400 mg kg^{-1}) to copper contamination with the maximum Cu accumulation (4.67 and 3.99) mg g^{-1}in leaves and shoots respectively).

Pardo et al. (2018) evaluated *Leptoplax emarginata* and *Alyssum murale* species for their nickel hyperaccumulation capacity. Ni was stored mostly in the leaves of plants and usually in the leaves of vegetative stems, also in flowers (in the case of *L. emarginata*, fruits). *A. murale* had a bit higher nickel yield than *L. emarginata*, nickel bioaccumulation of both species was related to the phenological stage of the plant and was maximum at mid-flowering (4.2 and 3.0 kg Ni ha^{-1}, respectively). The plant parts of *A. murale* that contributed most to nickel yield were flowering stems and leaves (75%), however, these were the stems and fruits at fruiting for *L. emarginata.*

In the study of Forte & Mutiti (2017), they have conducted a greenhouse experiment with *Hydrangea paniculata* and *Helianthus annuus. H. annuus* showed high accumulation of heavy metals in the shoots particularly the leaves (Cu, 368 ppm), and efficient translocation to the leaves. *H. paniculata* absorbed Pb and Cu in high concentrations but choosed to store more metals in the stems (Cu, 1757 ppm; Pb, 780 ppm) than in the leaves (Cu, 126 ppm; Pb, 35 ppm). *Hydrangea* stored more

metals in stems and leaves however showing a lower translocation ability than *Helianthus*.

Plant species belonging to the Lamiaceae family, mostly annual plants and shrubs, have been studied for heavy metal tolerance. *Petunia* and *Nicotiana* genera from the Solanaceae family are widely used as model plants in metal hyperaccumulation experiments. Both of these plants are very common plants, and many species have economic value in the horticultural market (Khan et al., 2021). Soil characteristics that can efffect the phytoremediation of heavy metals are; soil metal concentration, soil pH, soil texture, soil organic matter, redox potential and root zone, plant-bacteria interactions, clay content and cation exchange capacity (Laghlimi et al., 2015).

3. MOLECULAR MECHANISMS OF THE METAL HYPERACCUMULATION

The tolerance developed by the plant to a particular heavy metal is governed by a wide variety of interrelated physiological and molecular mechanisms, and understanding the genetic basis underlying these mechanisms is an important consideration for the use of plants in phytoremediation. Different plant species may have developed different mechanisms to tolerate excess heavy metals, and more than one mechanism may be at work even within a plant species. Plants often use the integrated effect of all the processes to tolerate the heavy metal stress (Hossain et al., 2012).

The molecular mechanisms of phytoremediation and gene manipulations are studied as a whole, through increased expression of metal chelator/carrier genes, increase in plant biomass, and reduction of oxidative stress and phytotoxicity and also minimizing public health risks. Nanoparticles and plant growth regulators (for example, auxin, gibberellin, and cytokinin) have also been shown to significantly dominate the increase of phytoremediation potential by minimizing the effect of various abiotic stress factors and enabling rapid growth of biomass (Rai et al., 2020).

Hyperaccumulator plants carry the heavy metals up to their shoots via xylem instead of holding the absorbed metal in their roots. Common or specific metal ion carriers or channels, complexing agents such as, amino acids, organic acids and H^+ ion coupled proteins binding to the metal species act as an intermediary in the energy dependent movement process of metals along the symplastic pathway.

Certain metals can be transported across cell membranes by these complexes, and their influx-efflux across cell membranes and displacement from roots to shoots may also be mediated by these complexes (Pasricha et al., 2021). The protein types take part in the translocation are; heavy-metal-trasporting ATPases (HMA), natural resistance-associated macrophage proteins (Nramp), cation diffusion faciliator (CDF) family, zinc-iron permease (ZIP) family, and MATE (Multidrug and toxin efflux) protein family. The plants sequestrate and then detoxify the heavy metal in the vacuoles after the metals are translocated and several transporter families exist in this network,

namely ATP-binding cassette (ABC), CDF, HMA and NRAMP transporters.

Besides carrier proteins, organic acids such as citrate, malate and oxalate are also involved in detoxification to aid metal ion retention and chelation. The part of amino acids in hyperaccumulatory plants is very important because they form stable complexes with bivalent cations and thus greatly assist in the sequestration of metal cations. There is a lot of evidence that histidine is involved in nickel hyperaccumulation (Singh et al., 2016).

In recent years, different roles of specialized metabolites (SM) synthesized in different tissues of metal-tolerant and/or hyperaccumulating species have been demonstrated. Among them, phytochelatins (PCs), metallothioneins (MT), heat shock proteins (hSP), nicotianamines (NAs), glutathione conjugate complexes (GS-X), cell wall proteins/pectins/polyphenols and related molecules contribute to metal detoxification mechanisms by chelating the metals (Thakur et al., 2016; Corso et al., 2020).

One of the major classes of heavy metal chelators known to plants are the phytochelatins (PCs), a Cys-rich peptide family. PCs are synthesized without translation from reduced glutathione (GSH) in a transpeptidation reaction catalyzed by the enzyme phytochelatin synthase (PCS). Therefore, the availability of glutathione in the plant, at least during their exposure to heavy metals, is crucial for PC synthesis (Yadav, 2010).

MTs are low molecular weight cytoplasmic metal binding proteins with a high proportion of cysteine (Cys) residues (7-10 kDa) and have been extensively characterized in a variety of prokaryotic and eukaryotic organisms. Plant MTs are classified into four types according to the arrangement of Cys residues; MT1, MT2, MT3 and MT4 subfamilies. MTs take very important tasks in ion homeostasis and tolerance in plants. Unlike PCs, which are the product of enzymatically synthesized peptides, MTs are synthesized as a result of mRNA translation (Emamverdian et al., 2015).

Following chelation, ligand-heavy metal complexes are transported actively from cytosol to the inactive compartments such as vacuoles. The transfer of the toxic metal ions away from the areas where vital metabolic activities of the cell ocur, provides an efficient precaution against the harmful results. Metal ions can also be separated and compartmentalized into other plant parts such as petioles, leaf sheaths, and trichomes, where the heavy metal is less damaging to the plant. Heavy metals can also be sent away from the plant stem by natural defoliation (Pasricha, et al., 2021).

In some cases, the strategies mentioned above could be insufficient to counteract the harmful effect of metals. As the metal ion amount in the cytoplasm increases, the production of reactive oxygen species (ROS) is stimulated, resulting in oxidative stress leading to disruption of cell homeostasis, DNA damage and protein oxidation. To overcome the oxidative damage problem caused by the heavy metals, plant cells induce a number of enzymatic (catalase, superoxide dismutase,

glutathione reductase and peroxidase) also non-enzymatic antioxidant compound (glutathione, carotenoids, flavonoids, including tocopherols and ascorbate) (Lajayer et al., 2019; Pasricha, et al., 2021).

The levels of antioxidant enzyme activities take a very important part in determining the tolerance and susceptibility levels of different species/genotypes under heavy metal stress. Effective scavenging activity preserves membrane lipid unity and essential macromolecules (Thakur et al., 2016; Antoniadis et al., 2017).

CONCLUSION

Since ornamental plants do not have the possibility to participate in the food chain, their contribution to the beautification of the environment with their aesthetic properties, and their possibility to be used industrially later, their acceptance by the public in herbal treatment applications is high. In addition, their decorative use in gardens and their participation in city planning projects increase their usability in herbal treatment.

However, in order to find the right plant for the right pollutant, screening studies should be continued with precision and the metal deposition mechanisms should be well understood. The use of plants that have adapted to local climate and soil conditions will provide effective growing environment

REFERENCES

Antoniadis, V., Levizou, E., Shaheen, S.M., Ok, Y.S., Sebastian, A., Baum, C., Prasad, M.N.V., Wenzel, W.W., & Rinklebe, J. (2017). Trace elements in the soil-plants interface: Phytoavailability, translocation, and phytoremediation-A review. Earth-Science Reviews, 171: 621-645.

Ashraf, S., Ali, K., Zahir, Z.A., Ashraf, S., & Asghar, H.N. (2019). Phytoremediation: Environmentally sustainable way for reclamation of heavy metal polluted soils. Ecotoxicology and Environmental Safety, 174: 714-727.

Babaoğlu Aydaş, S.S. (2008). Determination and Molecular Analysis of Nickel Accumulation at *Alyssum corsicum* (Brassicaceae) Grown in Tissue Culture Conditions. Ph.D. Thesis, Gazi University, Institute of Science,Ankara.

Baker, A.J.M. & Brooks, R.R. (1989). Terrestrial higher plants which hyperaccumulate metallic elements-a review of their distribution, ecology and phytochemistry. Biorecovery, 1: 81-126.

Baus, D. (2017). Overpopulation and The Impact on The Environment. Master Thesis, The City Univercity, Graduate Faculty, New York.

Briffa, J., Sinagra, E., & Blundell, R. (2020). Heavy metal pollution in the environment and their toxicological effects on humans. Heliyon, 6: e04691.

Capuana, M. (2020). A review of the performance of woody and herbaceous ornamental plants for phytoremediation in urban areas. Biogeosciences and Forestry, 13: 139-151.

Chatterjee, S.,Singh, L., Chattopadhyay, B., Datta, S., & Mukhopadhyay, S.K. (2012). A study on the waste metal remediation using floriculture at East Calcutta wetlands, a Ramsar site in India. Environmental Monitoring and Assessment, 184: 5139-5150.

Christaldi, A., Conti, G.O., Jho, E.H., Zuccarello, P., Grasso, A., Copat, C., & Ferrante, M. (2017). Phytoremediation of contaminated soils by heavy metals and PAHs. A brief review. Environmental Technology & Innovation, 8: 309-326.

Corso, M. & Torre, V.S.G. (2020). Biomoleculer approaches to understanding metal tolerance and hyperaccumulation in plants. Metallomics, 12: 840-859.

Cui, S., Zhang, T., Zhao, S., Li, P., Zhou, Q., Zhang, Q., & Han, Q. (2013). Evaluation of three ornamental plants for phytoremediation of Pb-contamined soil. International Journal of Phytoremediation, 15: 299-306.

Emamverdian, A., Ding, Y., Mokhberdoran, F., & Xie, Y. (2015). Heavy metal stress and some mechanisms of plant defense response. The Scientific World Journal, 2015: 756120.

Forte, J. & Mutiti, S. (2017). Phytoremediation potential of *Helianthus annuus* and *Hydrangea paniculata* in copper and lead-contaminated soil. Water Air Soil Pollution, 228: 77.

Goswami, S. & Das, S. (2016). Copper phytoremediation potential of *Calandula officinalis* L. and the role of antioxidant enzymes in metal tolerance. Ecotoxicology and Environmental Safety, 126: 211-218.

Han, Y., Chen, G., Chen, Y., & Shen, Z. (2015). Cadmium toxicity and alleviating effects of exogenous salicylic acid in *Iris hexagona*. Bulletin of Environmental Contamination and Toxicology, 95(6): 796-802.

Hossain, M.A., Piyatida, P., Teixeira da Silva, J.A., & Fujita, M. (2012). Molecular mechanism of heavy metal toxicity and tolerance in plants: Central role of glutathione in detoxification of reactive oxygen species and methylglyoxal and in heavy metal chelation. Journal of Botany, Vol. 2012: 37 pages.

Khan, A.H.A., Kiyani, A., Mirza, C.R., Butt, T.A., Barros, R., Ali, B., Igbal, M., & Yousaf, S. (2021). Ornamental plants for the phytoremediation of heavy metals: Present knowledge and future perspectives. Environmental Research, 195: 110780.

Kramer, U. (2010). Metal hyperaccumulation in plants. Annual Review of Plant Biology, 61: 517-534.

Kurade, M.B., Ha, Y.H., Xiong, J.Q., Govindwar, S.P., Jang, M., & Jeon, B.H. (2021). Phytoremediation as a green biotechnology tool for emerging environmental pollution: A step forward towards sustainable rehabilitation of the environment. Chemical Engineering Journal, 415: 129040.

Laghlimi, M., Baghdad, B., Hadi, H.E., & Bouabdli, A. (2015). Phytoremediation mechanisms of heavy metal contaminated soils: A review. Open Journal of Ecology, 5: 375-388.

Lajayer, B.A., Moghadam, N.K., Maghsoodi, M.R., Ghorbanpour, M., & Kariman, K. (2019). Phytoextraction of heavy metals from contaminated soil, water and atmosphere using ornamental plants: mechanisms and efficiency improvement strategies. Environmental Science and Pollution Research, 26: 8468-8484.

Lambert, M., Leven, B.A., & Green, R.M. (2000). New Methods of Cleaning Up Heavy Metal in Soils and Water. Environmental Science and Technology, Briefs for Citizens. Manhattan, Kansas State University.

Leitenmaier, B. & Küpper, H. (2013). Compartmentation and complexation of metals in hyperaccumulator plants. Frontiers in Plant Science, 4: 374.

Liu, J., Xin, X., & Zhou, Q. (2018). Phytoremediation of contaminated soils using ornamental plants. Environmental Reviews, 26: 43-54.

Liu, J., Zhou, Q., Sun, T., Ma, L., & Wang, S. (2008). Growth responses of three ornamental plants to Cd and Cd, Pb stress and their metal accumulation characteristics. Journal of Hazardous Materials, 151(1): 261-267.

Liu, Z., He, X., Chen, W., Yuan, F., Yan, K., & Tao, D. (2008) Accumulation and tolerance characteristics of cadmium in a potential hyperaccumulator, *Lonicera japonica* Thunb. Journal of Hazardous Materials, 169: 170-175.

Madanan, M.T., Shah, I.K., Varghese, G.K., & Kaushal, R.K. (2021). Application of aztec marigold (*Tagetes erecta* L.) for phytoremediation of heavy metal polluted lateritic soil. Environmental Chemistry and Exotoxicology, 3: 17-22.

Mahar, A., Wang, P., Ali, A., Awasthi, M.K., Lahori, A.H., Wang, Q., Li, R., & Zhang, Z. (2016). Challenges and opportunities in the phytoremediation of heavy metals contaminated soils: A review. Ecotoxicology and Environmental Safety, 126: 111-121.

Mani, D., Kumar, C., Patel, N.K., & Sivakuma, D. (2015). Enhanced clean-up of lead-contaminated alluvial soil through *Chrysanthemum indicum* L. Int. J. Environ. Sci. Technol, 12: 1211-1222.

Miao, Q. & Yan, J. (2012). Comparison of three ornamental plants for phytoextraction potential of chromium removal from tannery sludge. Journal of Material Cycles and Waste Management, 15(1): 98-105.

Mikail, N. & Çığ, A. (2020). Classification Of Ornamental Plant Species With Artifical Intelligence Applications. In Çığ, A. (Ed.), Ornamental plants: With Their Features and Usage Principles, Iksad Publishing House, Adıyaman, Turkey, pp: 67-92.

Pajevic, S., Borisev, M., Nikolic, N., Arsenov, D.D., Orlovic, S., & Zupunski, M. (2013). Phytoextraction of heavy metals by fast-growing trees: A Review. In Ansari, A.A. et al. (Ed.), Phytoremediation, Management of Environmental Vontaminants, Vol:3, Springer, Switzerland. pp: 29-64.

Pardo, T., Garrido, B.R., Saad, R.F., Vazquez, J.L.S., Vinas, M.L., Fernandez, A.P., Echevarria, G., Benizri, E., & Kidd, P.S. (2018). Assessing the agromining potential of Mediterranean nickel-hyperaccumulating plant species at field-scale in ultramafic soils under humid-temperate climate. Science of the Total Environment, 630: 275-286.

Pasricha, S., Mathur, V., Garg, A., Lenka, S., Verma, K., & Agarwal, S. (2021). Molecular mechanisms underlying heavy metal uptake, translocation and tolerance in hyperaccumulators-an analysis: Heavy metal tolerance in hyperaccumulators. Environmental Challenges, 4: 100197.

Prasad, M.N.V. (2004). Phytoremediation of metals and radionuclides in the environment: The case for natural hyperaccumulators, metal transporters, soil-amending chelators and transgenic plants. In Prasad, M.N.V. (Ed.), Heavy metal stres in plants, Springer, 2nd ed. India, pp: 345-391.

Rai, P.K., Kim, K.H., Lee, S.S., & Lee, J.H. (2020). Molecular mechanisms in phytoremediation of environmental contaminants and prospects of engineered transgenic plants/microbes. Science of the Total Environment, 705: 135858.

Selamat, S.N., Abdullah, S.R., & Idris, M. (2014). Phytoremediation of lead (Pb) and arsenic (As) by *Melastoma malabathricum* L. form contaminated soil in separate exposure. International Journal of Phytoremediation, 16(7-12): 694-703.

Singh, S., Parihar, P., Singh, R., Singh, V.P., Prasad, S.M. (2016). Heavy metal tolerance in plants: Role of transcriptomics, proteomics, metabolomics and lonomics. Frontiers in Plant Science, 6: 1143.

Thakur, S., Singh, L., Wahid, Z.A., Siddiqui, M.F., Atnaw, S.M., & Din, M.F.M. (2016). Plant-driven removal of heavy metals from soil: Uptake, translocation, tolerance mechanism, challenges, and future perspectives. Environmental Monitoring and Assessment, 188: 206.

Timothy, N. & Williams, E.T. (2019). Environmental pollution by heavy metal: An overview. International Journay of Environmental Chemistry, 3(2): 72-82.

Wang, Y., Wua, D., Wang, N., & Hua, S. (2011). Effect of *Chlorophytum comosum* growth on soil enzymatic activities of lead-contaminated soil. Procedia Environmental Sciences, 10: 709-714.

Wang, Y., Yan, A., Dai, J., Wang, N., & Wu, D. (2012). Accumulation and tolerance characteristics of cadmium in *Chlorophytum comosum*: A popular ornamental plant and potential Cd hyperaccumulator. Environmental Monitoring and Assesstment, 184: 929-937.

Yadav, S.K. (2010). Heavy metal toxicity in plants: An overview on the role of glutathione and phytochelatins in heavy metal stress tolerance of plants. South African Journal of Botany, 76: 167-179.

Yu, Z. & Zhou, Q. (2009). Growth responses and cadmium accumulation of *Mirabilis jalapa* L. under interaction between cadmium and phosphorus. J Hazard Mater, 167(1-3): 38-43.

URL-1: https://apps.who.int/iris/bitstream/handle/10665/107872/9789289071796-eng.pdf?sequence=1&isAllowed=y (Access date: 27.07.2021)

URL-2: https://www.intechopen.com/chapters/60680 (Access date: 16.07.2021)

CHAPTER IX

A WILD PLANT WITH ORNAMENTAL POTENTIAL: CURRENT APPROACHES AND FUTURE DIRECTIONS ABOUT SPECIES OF GENUS *Muscari* IN TURKEY

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INTRODUCTION

Turkey is an important center of plant diversity as it is the meeting point of three floristic regions and contain number of ornamental geophytes. These geophytes include a rich variety of bulbs, corms, tubers and rhizomes. Their above-ground organs like stems, leaves and flowers dry out after season and these plants continue to live under ground based on their storage organs until the next development period (Polat, 2018). Out of a total of 1056 taxa geophytes that grow naturally in Turkey, 424 are endemic (Yıldırım, 2020). One of the remarkable genus among these geophytes is *Muscari* Mill. The genus *Muscari*, was previously included in the Liliaceae family. It was later revised and included the Hyacinthaceae family. This classification was rerevised and the genus was included in the Asparagaceae family (Eroğlu, 2020). *Muscari*, a monocotyledonous plant, is a bulbous, perennial, herbaceous with 2 - 7 leaves lying at the base and along with more narrow leaves in upright position. Depending on the species and altitude, they usually bloom between February and May (URL-1). However, there are also species that bloom in August-October, in the fall months (*M. parviflorum)* (URL-1). Every spring, a new flower emerges from the bulbs of the plant, whose upper part dries up after it blooms and give seeds and mini muscari bulbils at the peripheral edges of the bulb stem (The number of bulbils in a cluster can be around 5-20 or more depending on the size of bulb). The bulbs are fleshy thick, raceme is dense and fleshy juicy, flowers are fertile, but flowers at the top are generally unproductive. These flowers, have a strong fragrance and are in racemus or spica state at the tip. The number of flowers in the cluster can be around 20-40.

The species in genus *Muscari* are generally fragrant, have white, blue, purple, green-blue and yellow flowers (Seçmen et al., 1995; URL-1).

Typically *Muscari* grows naturally in forest areas, stony slopes, steppes, close to streams and sand dunes or wet meadows and field edges or at any place up to about 3000 m above sea level in Turkey (Davis & Stuart, 1984). There are 51 reported species in genus *Muscari* in all of the southwest Asia, the Mediterranean region and Europe (Chittenden, 1956; Jafari & Maassoumi, 2011; Govaerts, 2019; Yıldırım, 2020). The genus *Muscari* was initially discovered by Davis & Stuart (1984), who showed the existence of twenty species in Turkey. The latest checklist of the genus *Muscari* of Turkey (Eker, 2012) has listed >30 species, all new species added to the Turkish flora after the final revision make a total number of 49 species (Table 1) (URL-1; URL-2; URL-3;URL-4; Yildirimli, 2010; Kayiran et al., 2019; Eker et al., 2019; Eker, 2019a; Eker, 2019b; Eker et al., 2020a; Eker et al., 2020b). The protection of these plants is of immense importance.

Table 1: *Muscari* taxon in Turkey

Number	Taxon Name (Local Name)	Endemic	General Distribution	General Distribution
1.	*M.racemosum* Mill. (Müşkürüm)	+	Southwest Anatolia	Turkey
2.	*M. macrocarpum* Sweet (Sarı müşkürüm)	-	Southwest Anatolia	Southeast Greece, Aegan
3.	*M. comosum* (L.) Mill. (Morbaş)	-	Turkey	Southwest and Central Europe, Mediterranean Countries, West Syria, Iran, Arabia, Caucasus
4.	*M. weissii* Freyn (Pembe sümbül)	-	Southwest Anatolia	Southeast Greece, Aegan
5.	*M. caucasicum* (Griseb.) Baker (Arap sümbülü)	-	Terrestrial Anatolia	Caucasus, Western, Northwest and Northern Iran
6.	*M. tenuiflorum* Tausch (Püsküllübaş)	-	Turkey	Central and South East Europe, Russia, Caucasus, Western Syria, Notrthern Iraq, Western Iran
7.	*M. longipes* Boiss. (Buğulu sümbül)	-	Anatolia	Caucasus, Western Syria, Northern Iraq, Iran
8.	*M. massayanum* C. Grunert (Şah müşkürüm)	+	South And East Anotolia	Turkey
9.	*M. mirum* Speta (Dirmil müşkürümü)	+	Southwest Turkey	Turkey
10.	*M. aucheri* (Boiss.) Baker (Gök müşkürüm)	+	Black Sea Main Aegean Section, Inner West Anatolian Section, Upper Sakarya Section, Upper	Turkey

			Euphrates Section, Antalya Section, Adana Section	
11.	*M. neglectum* Guss. ex Ten. (Arap üzümü)	-	Turkey	North Africa, South East England, Central Russia, Western Syria, Cyprus, Caucasus, Iran
12.	*M. discolor* Boiss. & Haussk. ex Boiss. (Alaca müşkürüm)	+	East Anotolia	Turkey
13.	*M. inconstrictum* Rech.f. (İnce müşkürüm)	-	South Anatolia	Cyprus, Northern Syria, Northern Iraq, Iran
14.	*M. latifolium* J. Kirk (Kaz sümbülü)	+	West and South Anatolia	Turkey
15.	*M. bourgaei* Baker (Top müşkürüm)	+	Northwest, West and South Anatolia	Turkey
16.	*M. sandrasicum* Karlén (Gökboncuk)	+	Southwest Anatolia	Turkey
17.	*Muscari microstomum* P. H.Davis & D. C. Stuart (Çayır müşkürüm)	+	Central Anatolia	Turkey
18.	*M. azureum* Fenzl. (Keşişbaşı)	+	Anatolia	Turkey
19.	*M. coeleste* Fomin (Kedi boncuğu)	+	East Anatolia	Turkey
20.	*M. macbeathianum* Kit Tan (Adana sümbülü)	+	South Anatolia	Turkey
21.	*M. parviflorum* Desf. (Güz müşkürüm)	-	Out of Anatolia	Mediterranean
22.	*M. babachii* Eker & Koyuncu (Tekin sümbülü)	+	South Anatolia (Hatay)	Turkey
23.	*M. racemosum* Mill. (Müşkürüm)	+	Southwest Anatolia	Turkey
24.	*M. sirnakence* Yild. (Şırnak sümbülü)	+	East Anatolia (Şırnak)	Turkey

25.	*M. sivrihisardaghlarensis* Yıld. & B.Selvi (Hisar sümbülü)	+	Central Anatolia	Turkey
26.	*M. turcicum* Uysal, Ertugrul & Dural (Türk müşkürümü)	+	South Anatolia (Midlle Taurus)	Turkey
27.	*M. tuzgoluensis* Yıld. (Tuz müşkürümü)	+	Central Anatolia (Akşaray)	Turkey
28.	*M. vuralii* Bağcı & Doğu (Mecit sümbülü)	+	South Anatolia (Karaman)	Turkey
29.	*M. erdalii* Özhatay & Demirci	+	South Anatolia (Mersin)	Turkey
30.	*M. tauricum* Demirci, Özhatay & E.Kaya	+	South Anatolia (Mersin)	Turkey
31.	*M. serpentinicum* Yıldırım, Altıoğlu & Pirhan	+	Southwest Anatolia (Sandıras Anadolu-Muğla)	Turkey
32.	*M. atillae* Yıldırım	+	East Anatolia (Levent Kanyon-Malatya)	Turkey
33.	*M. botryoides* (L.) Mill.	-	East Anatolia (Van)	Central and South Eastern Europe, Caucasus, Turkey
34.	*M. elmasii* Yıldırım	+	Southwest Anatolia (Muğla)	Turkey
35.	*M. fatmacereniae* Eker	+	South Anatolia (Adana)	Turkey
36.	*M. pamiryigidii* Eker (Yiğit sümbüllü)	+	Northwest Anatolia (Bolu, Mudurnu)	Turkey
37.	*M. pallens* (M.Bieb.) Fisch (Soluk müskürüm)	-	East Anatolia (Van)	Kafkasya, Gürcistan, Rusya

38.	*Muscari inundatum* (Hatay sümbüllü)	+	South Anatolia	Turkey
39.	*Muscari savranii* Uysal & Doğu (Savransümbülü)	+	Central Anatolia (Kayseri)	Turkey
40.	*M. haradjianii* Briq. Ex Rech.F.	+	Central South & South East	Turkey
41.	*M. nazimiyense* YILD & KILIÇ	+	East Mediterranean	South Medeterian
42.	*M. sabihapinariae* Eroğlu, Pınar & Fidan	+	South Anatolia (Adana, Sivas)	Turkey
43.	*M. muglaensis* Eker, H. Duman & Yıldırım	+	Sandıras Dağı (Muğla-Denizli)-Akdeniz-Ege	Turkey
44.	*M. sintenisii* Freyn (Meçhul müskürüm)	+	Blacksea (Gümüşhane -Trabzon)	Turkey
45.	*M. adilii* M.B. Güner & H.Duman (Bey sümbülü)	+	Central Anatolia	Turkey
46.	*M. anatolicum* Cowley & Özhatay (Ana müşkürüm)	+	South Anatolia	Turkey
47.	*M. armeniacum* Leichtlin ex Baker (Gavurbaşı)	-	Turkey	Yugoslavia, Bulgaria, Greece, Caucasus, Northwest Iranian
48.	*M. artvinense* Demirci & E.Kaya	+	East Blacksea	Turkey
49.	*M. kerkis* Karlén	-	Aegean	Turkey

1. PRODUCTION POTENTIAL AND MARKETING OF THE SPECIES OF GENUS *Muscari*

There is no market data or statistics on the import export or local production of the species in genus *Muscari* as these ornamental plants have a very specific and limited area in the landscape and ornamental plants industry (da Silva & Dobra'nszki, 2016). Turkey has the potential

to enable easy cultivation and marketing of *Muscari* and other geophytes due to to widespread wild populations of the species of this genus, favorable climatic conditions, and proximity to flower markets in Europe and the Middle East. Indeed, many of the species of genus *Muscari* are used as indoor and outdoor ornamentals since many years and have important place in Turkey's landscape industry. In the course of time many species among them have been successfully introduced as cultivated ornamental plants.

2. TRADE IN WILD SPECIES OF GENUS *Muscari*

Bulbous plants, including *Muscari* are among the geophytes with commercial value in the world (Kocak et al., 2019). Despite the fact that the export of wild bulbs, tubers and rhizomes etc. started in the middle of the 18th century, from the Second World War to the 1990s; when the bulbs were collected by the local people in the mountain villages of Anatolia under the monopoly of 4-5 companies that sent these collections to the Netherlands and then they were re-exported to other European countries or North America. All these practices were performformed with loose control or without any restriction in Turkey (URL-5).

In addition to these uncontrolled collection of bulbs and flowers from the wild; rapid population growth, urbanization, plowing and overgrazing for food and feed needs, intensive use of the chemicals to control pests, increasing tourism activities, forest fires, road widening activities and construction of highways, mines, poisonous gases from

factories and their unconscious collections have contributed negatively to their production under natural or wild conditions. It is known that populations of wild flower bulbs, tubers and rhizomes etc including Muscari have decreased significantly and many of them are in danger of extinction due to the above mentioned reasons (Aslan, 1992).

Ex situ and *in situ* strategies have been developed to prevent losses in plant genetic resources, protect biodiversity, and protect natural flowering species that are on the verge of extinction or decreasing for various reasons, which is one of the most important elements in their sustainable use. With the contributions of the Ministry of Agriculture and Rural Affairs, Universities, TUBITAK and voluntary environmental organizations, the propagation studies were started in the 1980s to reduce the destruction of these plants in wild and to discipline the export of flower bulbs.

Depending on these studies, the first regulations were prepared and published on January 24, 1989, the second on October 9, 1991, and the third on August 11, 1995, in the Official Gazette of the Turkish Republic. Many geophytes, which are in danger of extinction, were taken under protection by law and their export by removing wild was banned or restricted in the following years, The Turkish Republic Ministry of Food Agriculture and Livestoclk has prohibited uncontrolled collection of bulbous plants without permission through a regulation published in the official gazette. According to this regulation, many species belonging to the *Muscari* genus are considered ornamental plants and many of them are under threat in their wild

habitats. The communiqué on the export list of natural flower bulbs published by the Ministry of Food, Agriculture and Livestock in the Official Gazette in 2020, has prohibited to remove and export all *Muscari* natural bulbs in Turkey from 2021 (URL-6). The regulations are updated contnuously. Sustainable trade of the *Muscari* genus, can only be achieved by recognizing, breeding and protecting them as a gene source.

Ex situ conservation strategies can also be used for the protection of plant gene resources. Ex situ conservation of the plant can be achieved with traditional practices like formation of seed banks, arboretum, botanical gardens, and seed storage. Although seed storage, is generally one of the most preferred traditional method, where species suitable for clonal production can be preserved in field gene banks or they can be stored in the form of cold dormant vegetative tissues (without growing shoot buds). In addition to these methods, *in vitro* reproduction and protection methods, that is, biotechnological methods, can be applied to vegetatively propagated species (Bürün, 2021) and offer many advantages. These techniques provide advantages in collecting plant material, reproduction, international exchange and preservation of this geophyte (*Muscari*), which has an important place for Turkey and the world. The above mentioned methods facilitate in easy regeneration and production either through traditional or *in vitro* propagation techniques.

3. STUDIES ON *Muscari* SPECIES

Studies on *Muscari* species in Turkey can be examined under 3 headings:

3.1. Studies on the Comparison of Species in Genus *Muscari*

Studies on the morphology, anatomy, palynological and ecological characteristics or karyotype and molecular analyzes of *Muscari* species are important in terms of determining the related closeness among species and ancestral chromosomes in case of polyploids. Hopa (2005) examined the anatomical features of *M. comosum, M. neglectum* and endemic *M. latifolium*, *M. bourgaei* species in the Turkish province of Balikesir and observed that their general anatomical structures were similar, but there were differences in their cell size.

Açıkgöz (2007) identified two endemic geophytes, *M. aucheri* and *M. discolor* analyzed their anatomical features. They found simiilarity in the general structures of roots, scapes, bulbs and leaves; however distinguihed differences were observed in the arrangement and size of the cells. The palisade parenchyma is in two rows and the sponge parenchyma is irregularly arranged in *M. aucheri*. While in *M. discolor* has the palisade parenchyma in a single row, the sponge parenchyma is arranged quite regularly, and the two species differ in this respect.

Gürsoy & Şık (2010) studied *M. armeniacum* and *M. neglectum* collected from nine different localities and examined them in terms of morphological, anatomical, palynological and ecological features. It

was observed that the flower colors and seed morphologies of the species were different from each other. Root, stem, leaf cross sections and leaf superficial sections of the plant were examined for anatomical studies. Furthermore, they found the presence of raffide crystals and papilla-like protrusions on the leaf that were important in distinguishing the species.

Koşanay (2012) studied *M. neglectum*, collected from eight different localities. It was observed that the leaf thickness and length of the bulbs, and the seed morphologies were different from each other. Karyotype analyzes of bulbs belonging to plants collected from different populations showed differences in chromosome numbers.

Gürsoy (2016) compared the morphological, anatomical and ecological features of endemic *M. mirum* and *M. massayanum, Muscari tenuiflorum* and *Muscari latifolium* that showed very distinguished variations based on macromorphological features like bulbs, leaves and flowers. In the micromorphological examinations carried out by SEM, significant differences were observed in the seeds of the species, especially in testa ornamentations and pollen structures. It was determined that these species have family-specific characters in terms of anatomical features. In addition, the ecological demands of the species were determined by reaching the data that they grow in neutral and alkaline, partially acidic, salt-free, lime-free, low-lime or very high-calcareous soils, rich in organic matter, varying in micro and macro elements.

Demirci Kayıran & Özhatay (2017) studied the idiograms and karyotypes of 9 species in genus *Muscari* Mill. collected 21 populations of southern Turkish province of Kahramanmaraş. Researchers noted *M. armeniacum* 2n = 18 (diploid); *M. aucheri* 2n = 18 (diploid); *M. azureum* 2n = 18 (diploid); *M. babachii* 2n = 18 (diploid); *M. comosum* 2n = 18 (diploid); *M. tenuiflorum* 2n = 18 (diploid) *M. anatolicum* 2n = 27 (triploid); *M. neglectum* 2n = 18 (diploid), 36 (tetraploid), 54 (hexaploid); *M. parviflorum* 2n = 36 (tetraploid); and *M. anatolicum* 3n = 27 triploid chromosomes for the 1st time.

Al-Sammarraie (2020) studied endemic *M. macrocarpum* and *M. racemosum*. It is suggested that the species under investigation are actually sub-taxa of the same species, *M. macrocarpum* was reduced to the level of subspecies of *M. racemosum* subsp. *macrocarpum*. This is compliantly a new status for the species.

İlçim et al. (2020) studied morphological, anatomical, palinological characteristics of naturally distrubuted *M. inconstrictum, M. comosum, M. babachii* and *M. neglectum* species in Hatay Province (Turkey). Morphological studies were included to examine characters like bulb, leaves, flowers, fruits and seeds. The seed characters were found ovate-elliptic in *M. inconstrictum* and spheroidal in the others, with entire, rugose and ribbed ornamentation. Palynological analysis showed that pollen apertures were generally sulcate, subprolate and oblate in shape, and reticulate-subreticulate ornamentation. In anatomical studies, cross-sections were taken from the roots, stems and leaves of the

species by paraffin method. The prepared preparations were photographed using light microscope to catch the anatomical features.

3.2. Studies Based on Medicinal Properties of *Muscari* Species

Muscari species have been used in traditional medicine as antirheumatic, and treat stomach ailments, as diuretic and expectorant. The compounds called secondary metabolites in the structure of plants are generally known as alkaloids, phenolic acids and their derivatives, quinones, saponins, flavonoids, tannins and their derivatives, coumarins and terpenoids (Yücel Şengün & Öztürk, 2018). These secondary metabolites in plants are used in many areas due to the different effects of the components (Meydan, 2019). It has increased interest in the plants due to the fact that natural medicines can be produced from active ingredients obtained from the plants.

Uçar (2004) investigated the phytochemical properties of *M. bourgaei*, an endemic species, and determined that the plant contains mucilage, saponins, flavonoids, tannins and alkaloids.

Baba et al. (2014) studied *M. comosum* extract and determined that this extract stimulated some parameters in the non-specific immune system in fish compared to the control group. It was also determined that this dose affected the growth and development performance positively in the experimental group injected with these plant extracts at the rate of 2 mg/fish and showed a better result compared to control group.

In addition to stimulating the immune system, microbial activity studies are also used to determine the effect of active substances obtained from plants against pathogenic microorganisms. These studies are preferred because of their easy implementation and low cost (Canlı et al., 2016). Özkan et al. (2017) observed the cytotoxic and antioxidant activities of the extracts of *M. neglectum* and confirmed their using metal chelating capacity, ABTS cation radical and DPPH free radical scavenging activities. The cytotoxic potentials were determined by LDH and MTT tests on human cancer cell line HeLa and rat kidney cell line NRK-52E. The aqueous extracts herba (IC50: 8.52± 1.3 mg/mL) and the bulbs of *M. neglectum* (IC50: 2.83± 0.54 mg/mL) latter showed stronger DPPH free radical scavenging activity. Similarly, ethanol extracts from their bulbs also showed the maximum (27.88 %) ABTS scavenging activity of cation radicals.

The aqueous extracts from *M. neglectum* herba and bulbs showed the strongest metal chelating activity (28.99% and 28.07%, respectively) to the metal chelating activity test results, Similarly, Onaran & Bayram (2018) found that methanol extract obtained from the flower and flower stem of the *M. aucheri*. This plant, is very effective and potent against 5 different phytopathogens (*Botrytis cinerea, Rhizoctonia solani, Alternaria solani, Fusarium oxysporum f. sp. cucumerinum,* and *Verticillium dahliae*). 100% antifungal inhibition was noted using 20 and 10 mg/mL concentration against the pathogens.

3.3. Tissue Culture Studies and Field Trials on the Conservation and Commercial Reproduction of *Muscari* Species

3.3.1. Tissue Culture Studies

It is important to study all phases of plant regeneration system in tissue culture. These include seed germination, sterilization, gelling agents, regeneration media and their percentages, explant source, regeneration, rooting and adaptation to the external environments. These studies in the species of genus *Muscari* studied in Turkey are described below with the titles.

Seed germination: *Zantedeschia, Tulip, Rhododendron, Ranunculus, Ornithogalum, Orchis, Narcissus, Allium, Lilium, Iris, Hyacinthus, Hippeastrum, Gladiolus, Freesia, Cyclamen, Crocus, Anemone, Alstroemeria,* and *Muscari* are very valued geophytes and are popularly used for commercial production worldover. These geophytes are propagated both by conventional agronomic techniques and *in vitro* micropropagation techniques (Kocak et al., 2019). All species of genus Muscari have indeterminate habit of growth. Therefore, the seeds do not mature uniformly and the induced seeds have variable dormancy. The main causes of dormancy include insufficient maturity of the embryos inducing morphological dormancy. This also induce physical dormancy with variable permeability of the seed coat. Therefore, different researchers have used mechanical injuring of seeds and treatment with GA_3 to break and overcome these problems. Özgen & Arslan (2016), treated seeds of *M. azureum* with 0, 50, 100, 150 and 200 mg/L gibberellic acid for 3, 6 and 9 hours. Thereafter, the seeds

were sown in four replications in autumn in a mixture of burnt barn (manure prepared at a ratio of 1 percent), field soil, and sand (1:1:1). The percentage of emerging plants, plant height, root length, number of roots per plant fresh weight was compared. It was observed that gibberellic acid treatment durations and the doses significantly affected the germination of the seeds.

Sterilization: Since contamination in tissue culture adversely affect plant growth, it is of great importance to sterilize the nutrient medium, the tools and equipments and the explants.

Different disinfectants are used in sterilization of plant material. If the appropriate time and dose are not adjusted, problems such as contamination or disintegration of chlorophyll in plants ending up with necrosis on the tissues with patial to complete death. The most preferred disinfectants for species in the genus *Muscari* are bleach (5% NaOCl), ethyl alcohol H_2O_2, with or without Tween 20 etc. Thereafter, sterilization, the explants were rinsed with autoclaved distilled water for different durations of time under aseptic conditions (Ozel et al., 2009; Uranbey, 2010a; Uranbey, 2010b; Uranbey et al., 2010; Nasırcılar et al., 2011; Vaziri, 2014; Yücesan et al., 2014; Ozel et al., 2015; Özdemir et al. 2017; Fida, 2020).

Regeneration media: It is noted that the plant growth regulators and carbon source and gelling agents in the nutrient medium affect plant regeneration. Therefore it is necessarry to carefully use these after optimization to avoid difficulties in regeneration. MS (Özel et al., 2007;

Özel et al., 2009; Özel et al., 2015; Özel et al., 2016), LS (Yücesan et al., 2014), N6 (Uranbey, 2010a; Uzun et al., 2014) and Orchimax medium (Uranbey, 2010b) media have been used to regenerated different species in genus *Muscari*.

Generally the researchers have used 2-4 % sucrose (w/v) as a carbon source (Ozel et al., 2009; Ozel et al., 2015; Ozel et al., 2016; Nasırcılar et al., 2011; Uzun et al., 2014; Yücesan et al., 2014; Özdemir et al., 2017; Fida, 2020). Besides sucrose Vaziri et al. (2014) has used mannitol as a carbon source.

There is need to optimise the ratio of auxin, cytokinin and other plant growth regulators for regeneration. The researchers have generally preferred BAP, KIN, thidiazuron, zeatin, IAA, IBA, NAA, 2,4-D, Picloram (Ozel, 2008; Uranbey, 2010a; Nasırcılar et al., 2011; Vaziri et al., 2014; Özdemir et al., 2017; Fida, 2020).

Gelling agents and their ratios: The researchers have preferred using 0.6-0.8 % agar and 2 g/L gelrite at different as a thickener or gelling agent in the *in vitro* regeneration studies of genus *Muscari*. Vaziri (2009), Ozel et al., (2009), Uranbey (2011), Nasırcılar et al. (2011), Uzun et al. (2014), Yücesan et al. (2014), Özdemir et al. (2017) and Fida (2020) have reported use of 0.6-0.8%, 0.6%, 0.8%, 0.7%, 0.7%, 0.8%, 0.65%, 0.6 -0.7% (w/v) plant agar in the regeneration studies in the same order. Only Uranbey (2010a) has preferred to use 0.2% gelrite in the regeneration studies.

Explant source: Explant sources such as embryonic calli, 2-5 bulb scales, basal layer, of the bulbs, leaves, stems and immature zygotic embryos have been used to stimulate regeneration in different species of genus *Muscari* species (Ozel, 2008; Vaziri et al., 2009; Uranbey, 2010a, Uranbey, 2010b; Nasırcılar et al., 2011; Uzun et al., 2014; Yücesan et al., 2014; Özdemir et al., 2017 and Fida, 2020).

Regeneration: Propagation from seed is not a preferred method because the species in genus Muscari take a long time of three to five years to germinate and grow to reach a size desired for blooming under ideal conditions. If the growing plants face different types of biotic and abiotic stresses; this period could elongate.

Zygotic embryos are produced by the fertilized eggs; whereas, the somatic embryos are induced on the somatic cells, tissues, or organs using plant growth regulators under in vitro culture conditions.

Uranbey (2010a) propagated *M. azureum* with immature zygotic embryos. The researcher cultured the explants on N6 medium, fortified with 400 g/L casein hydrolysate + 40 g/L sucrose, 2 mg /L proline, 2 mg/L 2,4-D and 2 g/L gelrite for callus induction. The clusters of embryogenic callus were cultured on MS fortified with different doses of and combinations of Zeatin, KIN, BAP, thidiazuron, NAA, and IAA, 30 g/L sucrose and 7 g/L agar. The results indicated induction of > 13 bulblets/immature embryo after about 150-180 dof culture. the developing bulbs were rooted on ½ × MS medium fortified with 1 mg/L IBA, 0.5 g/L activated charcoal, 20 g/L sucrose gelled with 6 g/L agar.

Uzun et al. (2014) induced bulblet induction on immature zygotic embryos of *M. muscarimi* and noted 59 bulblets/explant on MS medium using 4 mg/L BAP and 0.5 mg/L NAA after 365 d of culture. The bulblets were rooted on MS rooting medium and showed increased size after two months. About 5% the rooted bulbs were successfully acclimatized to external conditions.

Vaziri et al. (2014) propagated *M. aucheri* immature embryos and bulb scales using MS medium fortified with 2 mg/L 2,4-D, 40 g/L mannitol and different concentrations and combinations BAP, Kinetin, thidiazuron+ GA_4+ IAA, IBA and 2 mg/L agar. The maximum number of 51.7 bulblets were noted on MS medium fortified with 2.0 mg/L KIN + 0.2 mg/L IBA. The highest number of 18.3 bulblets per immature embryo explants were noted on MS medium fortified with 0.5 mg/L KIN, 2 mg/L BAP and 0.25 mg/L IBA.

Yücesan et al. (2014) obtained 7.9 somatic embryos/explant post 70 d on LS medium having 2 mg/L BA.

Synthetic seed production is one of the important techniques in plant cell and tissue culture. These seeds are made up of plant tissues or somatic embryos artificially encapsulated with alginate hydrogel. Synthetic seed technology has significant effect on the conservation of the plant tissues and sustainability of the plants. The state has started emphasising conservation of the plant species during last few decades.

Green nodular calli induced on LS medium containing 5 mg/L BA + 0.5 mg/L NAA or 5 mg/L BA were used by Yücesan et al. (2014) to induce somatic embryos. They embedded the induced embryos with sodium alginate and transferred them to LS medium supplemented with or without 0.5 or 1.0 mg/L GA_3 for 42 d. The synthetic seeds (encapsulated bulblets) were stored at 4 °C in dark. They retained their viability after 70 d.

Chipping is the most common method of regeneration in species in genus *Muscari* and is widely used in the species of genus Muscari under *in vitro* conditions. The bulbs induced on chips reach the blooming in a shorter time compared to the bulbs obtained by the method of cutting into two, four or even five scales. *Muscari* is among the species that respond well to this method. The aim is to obtain more bulbs from the mother bulb. At the base of each of these scales, one or several 5-10 lateral juvenile bulbs are formed on the basal body or the base. It is possible to induce 5-20 juvenile bulbs on these scales that are very vigorous and could bloom in 3-5 years. Uranbey (2010b) propagated *M. aucheri* using 2-4 bulb scales on Orchimax and Nitsch & Nitsch Media fortified with 2 mg/L 2,4-D, 20 mg/L mannitol, 20 mg/L sucrose, 0.5 mg/L NAA and different doses of BAP, KIN, 2iP and thidiazuron on 2g/L gelrite solidified medium. The medium was solidified with 2 mg/L. The bulblet induction was noted on both media. using BAP, KIN and 2-iP on 2-4 bulb scales. The maximum number of bulblets was noted on the Orchimax medium fortified with 1 mg/L KIN and 2 mg/L KIN, respectively. The highest number of bulblets per explant was

noted on 4 scales using Nitsch & Nitsch medium fortified with 2 mg/L BAP. The Nitsch & Nitsch medium induced maximum number of bulbs on 10 mg/L 2-iP on 2 scales. These were acclimatized and transferred to field conditions.

Uranbey et al. (2010) induced *M. azureum* bulblet regeneration on Orchimaxmedium containing 2 mg/L 2,4-D, 20 g/L mannitol, 20 g/L sucrose, 0.5 mg/L NAA and different concentrations of BAP, KIN, 2iP and thidiazuron plus 2 g/L gelrite using 2–4 bulb scale explants. The best regeneration of 8.77 bulblets per explant was exhibited on 2 mg/L BAP, 2 mg/L 2,4-D, 20 g/L mannitol, 20 g/L sucrose and 0.5 mg/L NAA in Orchimax medium using 2-scales The mature bulbs were excised rooted on ½ × MS medium containing 1 mg/L IBA, 0.5 g/L activated charcoal, 20 g/L sucrose and 6 g/L agar. These were acclimatized with a 14% survival rate after 21 d.

Nasırcılar et al. (2011) developed a protocol for *in vitro* propagation of *M. mirum* Speta using 4 scales. *M. mirum* strain was treated with different concentrations of BAP, NAA, thidiazuron, picloram, 2,4-D and cultured in different nutrient media. The maximum number of 23.50 bulblets per explant from 4 scale bulb explants were noted after 150 d on MS medium. Rooted bulbs larger than 5 mm in diameter were cultured on a 1:1:1 mixture of perlite soil and vermiculite. No abberation in chromosomes 2n = 18was noted.

The most preferred explant is obtained through chipping using double scales. Capacity to induce new bulblets on double scales differs in each

of the species in genus *Muscari*. For example, *M. macrocarpum* (Ozel et al., 2007; Ozel et al., 2009), *M. adilii* (endemic) (Ozel, 2008), *M. muscarimi* (endemic) (Ozel et al., 2015), *M. neglectum* (Ozel & Ünal, 2016) were studied and different numbers of bulbs were obtained from double scales. The maximum number of 19 bulbs were induced on MS medium fortified with 4 mg/L BAP-2 mg/L NAA using *M. muscarimi*. The bulbs had diameter of 1.24 cm on MS medium containing 1 mg/L BAP–1 mg/L NAA. The highest number of six *M. macrocarpum* bulbs per explant was exhibited on MS medium fortified 2 mg/L Kinetin-0,5 mg/L NAA. They noted the largest bulbs having a diameter of 1.39 cm on the MS medium fortified with 4 mg/L Kinetin-2 mg/L NAA on MS medium. The maximum number of 8.25 bulbs per explant were noted on 0.1 mg/L thidiazuron-0.5 mg/L NAA in *M. neglectum*. However, the largest bulbs of about 0.47-0.48 cm diameter were noted on MS medium containing 0.15 mg/L thidiazuron 0.5 and 2 mg/L NAA. The highest number of 15.75 bulblets per explant were noted on MS medium fortified 4 mg/L BAP- 0.5 mg/L NAA in *M. adilii*. The maximum diameter of 54-58 mm was noted on MS medium having 1 mg/L BAP and 2 mg/L NAA.

Fida (2020) developed propagation techniques for multiplication of *M. neglectum* Guss. under *in vitro* conditions using two, three, four, and five bulb scales and bulblets explants. According to the results, freshly harvested bulbs were not suitable for micropropagation due to development of necrosis on the explants. However, the bulb regeneration on the scales of bulb stored for 6 weeks under dark

conditions ranged 13.33 to 100%. In addition, 100% callus formation was observed on 2-bulb scales using MS medium containing 1 mg/L BAP + 0.8, 1.0 and 1.20 mg/L NAA (3 combinations). In addition, 1.93 bulblets with bulb diameter of 0.97 cm (the largest) was observed on MS medium containing 1 mg/L BAP + 0.4 mg/L NAA. In the same cultures medium, 100% bulb formation and 2.89-3.38 axillary and 3.00-4.00 adventitious bulblet formation was observed on other (three, four and five bulb scales) explants. The largest bulblets developed on two-scale explants were rooted on ½ ×MS medium containing 0.5 mg/L NAA. It is concluded that the results obtained for *M. neglectum* are of great importance for commercial production.

Stem segments have also been used as explant in *Muscari* studies. Özdemir et al. (2017) used stem explants on MS medium containing, thidiazuron + NAA (12 combinations) to induce regeneration on MS medium. Maximum number of bulblets per explant was noted on MS medium containing 3 mg/L thidiazuron + 0.4 mg/L NAA with maximum number of bulbs on MS medium fortified with 5 mg/L thidiazuron + 0.2 mg/L NAA. The bulblets were cultured on MS medium fortified 40 g/L sucrose; root and gain bulb diameter.

Lower regenerations was noted on other explants compared to bulb scales. Ozel (2008) micropropagated bulblets on lower portions of leaves of *M. muscarimi*, taken as explant. the best regeneration medium was 4 mg/L BAP- 0.5 mg/L NAA, that induced 2-3 cm thick bulbs. The largest bulbs were noted on 4 mg/L BAP-2 mg/L NAA.

Nasırcılar et al. (2011) on the other hand, used leaf explants NAA, 2,4-D, and picloram along with several concentrations of BAP for bulblet regeneration using bulb sales and leaves of *M. mirum*. No bulbs was induced on leaf and scale explants. Approximately 50% the bulb scales induced calli on MS medium fortified with 1 or 2 mg/ L 2,4-D after 15 days of culture.

Rooting and adaptation: Another problem *in vitro Muscari* studies is the rooting and transferring bulbs to open air conditions in the fields. The species in genus *Muscari* may need an auxin or an auxin-free medium (Ozel et al., 2009; Ozel et al., 2016) for their rooting. There are reports of rooting species in genus *Muscari* using MS medium containing IBA or NAA (Uranbey, 2010a; Uranbey, 2010b; Uranbey et al., 2010; Nasırcılar et al., 2011; Uzun et al. 2014; Ozel et al., 2015; Özdemir et al., 2017; Fida, 2020) with varying percentage of rooting and adaptation to the open air environment. Vaziri et al. (2014) rooted *M. aucheri* on ½ ×MS medium sfortified with 1 mg/L NAA, and gelled with 6 g/L agar. The rooted bulblets were transplanted to pots containing potting mixture and acclimatizated in the growth chamber. Only 17% bulbs survived.

3.3.2. Agronomic Studies

Only two studies have been reported on the *M. armeniacum*, one on *M. azureum* by the same author.

Kahraman (2019) compared the effects of plucking flower buds at 3 different developmental stages on raceme length, raceme diameter plant

weight, pedicel length, pedicel diameter, leaf width, leaf thickness, number of leaves, leaf length, number of flowers in raceme, number of bulblets, bulb diameter of *M. armeniacum*. Plucking of flower buds stopped generative growth resulting in improved bulb diameter and induction of number of bulblets on the mother bulbs.

In the second experiment, Kahraman (2020) compared the effects of different sowing and stratification times on the germination of seeds of *M. azureum*. The researcher used 60 and 120 days stored seeds stratified for 15, 30, 45 and 60 days. It was followed by sowing them in pots and treating with light colors (daylight, daylight + red, daylight + blue and daylight + purple). The researcher potted the seeds in the second group on peat, cocopeat, vermiculite and perlite in the greenhouse. The researcher determined the peat as the best medium for germination.

Kahraman (2020) compared the performance of *M. armeniacum* by planting 3.5 cm circumference bulbs at different planting depths on mixture of perlite + peat + cocopeat (1: 1: 1) at a depth of 1 cm, 4 cm and 7 cm. These were irrigated and fertilised soon after planting. The experiment was conducted as a randomized block design using three replications and 10 bulbs per pot. In the experiment, biometric measurements including emergence number, EC, pH, plant weight, bulb diameter, weight, bulblet number, number of adventitious roots, length, weight, number of leaves, their length, width and weight were determined. The highest emergence (50%) was noted on bulbs planted at depth of 1 cm, and the highest plant weight (3.79 g) was noted on the bulbs planted at depth of 4 cm. The effect of planting depth on the other

parameters was non significant. The bulb diameter was 14.37-15.42 mm, the bulb weight was 1.79-2.11 g, the number of bulblet was 1.00-1.40, the leaf length was 22.88-24.50 cm, the leaf width was 3.64-3.81 mm and the root length was between 8.56-11.50 mm.

CONCLUSION

There is very limited available data on commercial propagation of the species in genus *Muscari*, as presently they occupy a very specific and limited space in the landscape and ornamental plants industry. This review mentions and discuss the studies on general features of the species in the genus *Muscari*, their modes of propagation including karyological, taxonomic, agronomic and tissue culture based works under Turkish conditions. Biotechnological achievements for *Muscari* species are still in their infancy and discovery phase. Further studies on these plants are needed. It is assumed that these studies will improve and contribute to this knowledge. An active participation and collaborations of industry, universities and-reaearch centres is needed with the participation of biotechnologists, agronomists, managers of environment protection, civil engineers involved in construction of dams, roads and planners to save our local germplasm.

REFERENCES

Açıkgöz, R. (2007). The Anatomıcal Characteristics of Endemics Muscari aucheri (Boıis.) Baker and Muscari discolor Boiss. & Hausskn Species Distributed in Turkey. M.Sc. Thesis, Selçuk University, Institute of Science, Konya, Turkey.

Al-Sammarraie, O.F.A. (2020). The Comparison of Genotype and Cytotypes of *Muscari macrocarpum* Sweet and *Muscari racemosum* Mill., Selçuk University, M.Sc. Thesis, Institute of Science, Konya, Turkey.

Aslan, N. (1992). Conservation of Natural Economic Crops. Journal of Agriculture and Village, 74: 17-19, Ankara.

Baba, E., Uluköy, G., & Mammadov, R. (2014). Effects of *Muscari comosum* extract on nonspecific immune parameters in gilthead seabream, *Sparus aurata* (L. 1758). Journal of the World Aquaculture Society, 45(2), 173-182.

Bürün, B. (2021). The Use of Biotechnology in Conservation of plant Biodiversity and Studies in Turkey. Eskişehir Technical University Journal of Science and Technology C- Life Sciences and Biotechnology, 10(1): 1-16.

Canlı, K., Yetgin, A., Akata, I. & Altuner, E.M. (2016). *In vitro* antimicrobial activity of *Angelica sylvestris* Roots. International Journal of Biological Sciences, 1(1): 1-7.

Chittenden, F.J. (1956). Dictionary of gardening. Clarendon Press, Oxford, 3: 1329-1331.

da Silva, J.A.T. & Dobránszki, J. (2016). Tissue culture of *Muscari* species: present achievements and future perspectives. Rendiconti Lincei, 27(3): 427-441.

Davis P.H. & Stuart D.C. (1984). Flora of Turkey and the East Aegean Islands. In Miller in Davis P.H. . [ed.], M*uscari* vol. 8, Edinburgh U niv. ePress, I984. pp: 245- 265.

Demirci Kayiran, S. & Özhatay, F.N. (2017). A karyomorphological study on the genus *Muscari* Mill. growing in Kahramanmaraş (Turkey). Turkish Journal of Botany, 41(3): 289-298.

Eker, I. & Kandemir, A. (2020b). Taxonomic resurrection of *Muscari sintenisii* Freyn (Asparagaceae) and lectotypification of the species. Bağ-Bahçe Science Journal, 7(3): 12-24.

Eker, I. (2012). *Muscari* Mill. – In: Güner, A. [ed.],A Checklist of Flora of Turkey (Vascular Plants). Nezahat Gökyiğit Botanic Garden and Flora Research Association Publication, İstanbul, 98-100.

Eker, I. (2019a). *Muscari fatmacereniae* (Asparagaceae, Scilloideae), a new species from southern Anatolia. Phytotaxa, 397(1): 99-106.

Eker, I. (2019b). *Muscari pamiryigidii* (Asparagaceae, Scilloideae), a new species from Northwestern Anatolia. Phytotaxa, 408(4): 255-266.

Eker, I., Duman, H., & Yıldırım, H. (2020a). *Muscari muglaensis* (Asparagaceae, Scilloideae), a new species from Southwestern Anatolia. Phytotaxa, 475(4): 267-278.

Eker, İ., Yıldırım, H., & Armağan, M. (2019). A new grape hyacinth record for the flora of Turkey: *Muscari pallens* (M. Bieb.) Fisch. (Asparagaceae). Vineyard Science Journal, 6(1): 45-53.

Eroğlu, H. (2020). Morphology, Palinology and Seed Surface Researches on the Taxa of Genus *Muscari* Mill. (Asparagaceae) Spreads in Turkey, Ph.D. Thesis, Van Yüzüncü Yıl University, Institute of Science, Van, Turkey.

Fida, A. (2020). *In vitro* Propogation of *Muscari neglectum* Guss. widely Grown in the Natural Flora of Van Region, M.Sc. Thesis, Van Yüzüncü Yıl University, Institute of Natural and Applied Sciences, Van, Turkey.

Govaerts, R. (2019). World checklist of Asparagaceae. Facilitated by the Royal Botanic Gardens, Kew. Retrieved April 15, 2019 from http://apps.kew.org/wcsp

Gürsoy, M. (2016). Morphological, Anatomical and Ecologigal Features of *Muscari mirum* Speta (Asparagaceae) and It's Allied (*Muscari massayanum* Grunert, *Muscari tenuiflorum* Tausch and *Muscari latifolium* Kirk) Species, Ph.D. Thesis, Celal Bayar University, Institute of Natural and Applied Sciences, Manisa, Turkey.

Gürsoy, M. & Şık, L. (2010). Comparative anatomical studies on *Muscari armeniacum* Leichtlin ex Baker and *Muscari neglegtum* Guss. In west Anatoli. Celal Bayar University Journal of Science, 6(1): 61-72.

Hopa, E. (2005). Anatomy and Morphology of *Muscari* sp. Grown in Balıkesir, M.Sc. Thesis, Balıkesir University, Institute Of Science, Balıkesir, Turkey.

İlçim, A., Karataş, H., & Karahan, F. (2020). Comparative morphological, anatomical and palynological studies on some *Muscari* Mill. Species (Asparagaceae). Journal of the Institute of Science and Technology, 10(2): 846-854.

Jafari, A. & Maassoumi, A.A. (2011). Synopsis of *Leopoldia, Muscari* and *Pseudomuscari* (Hyacinthaceae) in Iran, with *Leopoldia ghouschtchiensis* sp. nova. In: Annales Botanici Fennici Finnish Zoological and Botanical Publishing Board. 48(5): 396-400.

Kahraman, Ö. (2019). The effects of plucking flower bud on bulb and plant growth of *Muscari armeniacum* Leichtlin ex Baker in different developmental periods. Anadolu Journal of Agricultural Sciences, 34(1): 12-17.

Kahraman, Ö. (2020). Growing of *Muscari armeniacum* (Grape Hyacinth) at different planting depths. Kahramanmaraş Sütçü İmam University Journal of Agriculture and Naure, 23(6): 1441-1448.

Kayiran, S.D., Özhatay, N., & Kaya, E. (2019). *Muscari tauricum* (Asparagaceae, Scilloideae), a new species from Turkey. Phytotaxa, 399(2): 109-118.

Kocak, M., Sevindik, B., Izgu, T., Tutuncu, M., & Mendi, Y.Y. (2019). Synthetic Seed Production of Flower Bulbs. In Synthetic Seeds. Springer, Cham. pp: 283-299.

Koşanay, G. (2012). The Morphological, Anatomical and Karyological Investigations on *Muscari Neglectum* Guss. Species Growing in Different Populations, M.Sc. Thesis, Trakya University, Institute of Science Edirne, Turkey.

Meydan, İ. (2019). Characterization of ethanol extract and oil with GS-MS of almond (*Amygdalus trichamygdalus*) fruit. Information Technology and Aplication Science, 14(2): 241-250.

Nasırcılar, A.G., Mirici, S., Karagüzel, Ö. , Eren, Ö., & Baktir, İ. (2011). *In vitro* propagation of endemic and endangered *Muscari mirum* from different explant types. Turkish Journal of Botany, 35: 37-43.

Onaran, A. & Bayram, M. (2018). Determination of antifungal activity and phenolic compounds of endemic *Muscari aucheri* (Boiss.) Baker extract. Journal of Agricultural Faculty of Gaziosmanpasa University, 35(1): 60-67.

Ozel Ç.A. (2008). *In vitro* bulblet production of different *Muscari* species, Ph.D. Thesis, Gazi University, Institue of Science and Technology, Ankara, Turkey.

Ozel, C.A., Khawar, K.M., & Unal, F. (2007). *In vitro* axillary bulblet regeneration of Turkish yellow grape hyacinth (*Muscari macrocarpum* Sweet) from twin scale explants. Research Journal of Agriculture and Biological Sciences, 3(6): 924-929.

Ozel, C.A., Khawar, K.M., & Unal, F. (2015). Factors affecting efficient in vitro micropropagation of *Muscari muscarimi* Medikus using twin bulb scale. Saudi Journal of Biological Sciences, 22(2): 132-138.

Ozel, C.A., Khawar, K.M., Arslan, O., & Unal, F. (2009). *In vitro* propagation of the golden grape hyacinth (*Muscari macrocarpum* Sweet) from twin scale explants. Propagation of Ornamental Plants, 9(4): 169-175.

Ozel, Ç.A. & Ünal, F. (2016). Efficient *in vitro* clonal propagation of *Muscari neglectum* Guss. Ex. Ten using thidiazuron-α naphthalene acetic acid. Turkish Journal of Agriculture-Food Science and Technology, 4(12): 1173-1178.

Özdemir, F.A., Kılıç, Ö., & Bağcı, E. (2017). *In vitro* bulb regeneration from stem explants of endemic geophyt *Muscari aucheri* (Boiss.) Baker. International Journal of Secondary Metabolite, 4(3), Special Issue 1: 50-54.

Özgen, Y. & Arslan, N. (2016). The effects of different gibberellic acid doses and application times on the emergence of Muscari azureum Fenzl (Keşişbaşı) seeds. VI. Ornamental Plant Congress, Proceeding, 19-22 April 2016, Antalya, Turkey pp: 313-318.

Özkan, E.E., Kayıran, S.D., Taşkın, T., & Abudayyak, M. (2017). *In vitro* antioxidant and cytotoxic activity of *Muscari neglectum* growing in Turkey. Marmara Pharmaceutical Journal, 22(1): 74-79.

Öztürk, S.D.K., Yıldırım, B.Ş., & Yıldız, H. (2021). Contribution of genetic and chromosome engineering studies from past to present to sustainable agriculture and plant breeding. YYU Journal of Agricultural Science), 31(1): 246-258.

Polat, Z. (2018). Effects of Different Forcing Treatments on The Cut Flower Performance of Tulip (*Tulipa gesneriana* L.). M.Sc. Thesis, Ankara University, Graduate School of Natural and Applied Sciences, Ankara, Turkey.

Seçmen, Ö., Gemici, Y., Görk, G., Bekat, L., Leblebeci, E. (1995) Seed Plant Systematic. Ege University Faculty of Science Book Series, 4. Edition, İzmir, Turkey pp: 323-325.

Uçar, N. (2004). Some Phytochemical Analysis *on Muscari bourgaei* Baker, M.Sc. Thesis, Muğla University, Graduate School of Natural and Applied Sciences, Muğla, Turkey.

Uranbey, S. (2010a). *In vitro* bulblet regeneration from immature embryos of *Muscari azureum*. African Journal of Biotechnology, 9(32): 5121-5125.

Uranbey, S. (2010b). Stimulating effects of different basal media and cytokinine types on regeneration of endemic and endangered *Muscari aucheri*. Archives Biology of Science, 62(3): 663-667.

Uranbey, S., İpek, A., Caliskan, M., Dundar, E., Cocu, S., Basalma, D., & Guneylioglu, H. (2010). *In vitro* bulblet induction from bulb scales of endangered ornamental plant *Muscari azureum*. Biotechnology & Biotechnological Equipment, 24(2): 1843-1848.

Uzun, S., Parmaksiz, I., Uranbey, S., Mirici, S., Sarıhan, E.O., İpek, A., ... & Özcan, S. (2014). *In vitro* micropropagation from immature embryos of the endemic and endangered *Muscari muscarimi* Medik. Turkish Journal of Biology, 38(1): 83-88.

Vaziri, P.A., Uranbey, S., & Sancak, C. (2014). Efficient *in vitro* microprapagation for the conservation of endemic and endangered aucher-eloy grape hyacinth [*Muscari aucheri* (Boiss.) Baker]. Journal of Applied Biological Sciences, 8(1): 80-83.

Yıldırım, Ö. (2020). Research on the seed Reproduction of Keşişbaşı (*Muscari azureum* Fenzl.) M.Sc. Thesis, Ahievran University, Graduate School Of Science, Kırşehir, Turkey.

Yildirimli, S. (2010). Some new taxa, records and taxonomic treatments from Turkey. The Herb Journal of Systematic Botany, 17(2): 1-114.

Yücel Şengün, İ. & Öztürk, B. (2018). Some natural antimicrobials of plant origin. Anadolu University Journal of Science and Technology C- Life Sciences and Biotechnology, 7(2): 256-276.

Yücesan, B.B., Cicek, F., & Gürel, E. (2014). Somatic embryogenesis and encapsulation of immature bulblets of an ornamental species, grape hyacinths (*Muscari armeniacum* Leichtlin ex Baker). Turkish Journal of Agriculture and Forestry, 38(5): 716-722.

URL-1: http://www.tubives.com/ (Access date: 12.06.2021)

URL-2: https://www.ipni.org/ (Access date: 12.06.2021)

URL-3: https://wcsp.science.kew.org/qsearch.do (Access date: 12.06.2021)

URL-4: Eker, I. (2012). Bizimbitkiler http://www.bizimbitkiler.org.tr (Access date: 11. 07. 2021)

URL-5: https://tarekoder.org/1998ankara/26.pdf (Access date: 10.07.2021)

URL-6: https://www.resmigazete.gov.tr/eskiler/2020/12/20201218-6.htm (Access date: 18.05.2021)

CHAPTER X

THE MORPHOLOGICAL CHARACTERIZATION OF SOME ORNAMENTAL PEPPER LINES IN THE GENETICS COLLECTION OF MUSTAFA KEMAL UNIVERSITY

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INTRODUCTION

The pepper (*Capsicum* spp.) has been used for food of human since 7000 BC and has been planted since 5000 BC in South America (Perry et al., 2007). Even though Turkey is not gene center of *Capsicum*, which is greatest diversity can be found, it has been cultivated and used there for an estimated 300－400 years. Pepper has taken its place in many traditional local foods in our country (Mavi et al., 2013).

Popularly, the word pepper is used to designate the condiment spicy derived from several different plants with very different origins diverse. Among the many known peppers, there are one of the genus *Capsicum*, of the Solanaceae family. These peppers have as a characteristic, which distinguishes them from the others, the presence of capsaicin, a substance responsible for pungency, the degree of which varies according to the species and type of pepper. Red pepper, sweet pepper and chili pepper are fruits of several species of this genus. Peppers are highly valued in world cuisine. In addition, its pigments, aromas and pungent substances are widely used in industries. Pepper extracts are used in cosmetic and pharmaceutical products. Peppers are also used as ornamental plants (Bosland & Votova, 1999).

Ornamental peppers are a member of the *Solanaceae* family, which includes many species of ornamental plant value as a *Brugmansia*, *Datura*, *Petunia*, *Nicotiana* and *Brunfelsia*. In addition, ornamental peppers are often confused with *Solanum pseudocapsicum* and *Solanum capsicastrum* species, which are used as potted ornamental plants.

However, ornamental peppers differ from these species in that they are included in the *Capsicum* genus and their edible fruits. Many cultivars within the genus *Capsicum* have esthetic value for decorative uses in the garden and as indoor potted plants. Ornamental peppers can provide a range of fruit shapes and colors complemented by very attractive leaf colors that are green, purple or variegated. The ornamental peppers classified by cultivars within all domesticated species: *Capsicum annuum* L., *Capsicum chinense* Jacq., *C. frutescens, C. pubescens* and *Capsicum baccatum* var. *pendulum* Willd. The genus *Capsicum* contains worldwide economically important species. *Capsicum annuum* L. is the most cultivated species among them, with a wide variety of forms and colors of its morphological features, great floriculture (ornamental) capability (Stommel & Bosland, 2006). In Turkey, species other than *C. annuum* are not well known, although their cultivation and production is not carried out, a variety of materials have been brought for breeding and hobby purposes.

The use of ornamental peppers is not limited to ornamental potted peppers alone. Ornamental peppers have a wide variety from short and tight-shaped and small-fruited (Piquen) varieties such as 'Holiday Cheer' to large-fruited varieties that can grow up to 1 meter such as 'NuMex Mirasol'. The wide variety of plant habitats and fruit types allows them to be used as potted ornamental plants, while some other types can be used as cut flowers and outdoor ornamental plants (Stommel & Bosland, 2006).

Most of the ornamental pepper varieties have very pungent fruit. Varieties such as 'Medusa' and 'Chilly Chili' have become popular due to their non-pungent fruits. They are also used as outdoor ornamental plants. Miniature, beautifully colored sweet peppers are suitable for fresh consumption and ornamental use. This morphological diversity offers numerous opportunities to develop unique ornamental pepper varieties. Cut floriculture in ornamental peppers is an important type of use in Europe and its importance has increased in recent years. 'NuMex Mirasol' is a type of pepper used as cut flower in flower arrangements. This ornamental pepper; that develops as bunches of fruit on a long stalk. Numex Mirasol fruits are spiky and perpendicular. Approximately 16 bunches per plant and 6 fruit in each bunch, a development in the form of a multi-stemmed bush (Stommel & Bosland, 2006).

'NuMex Sunset', 'NuMex Sunrise' and 'NuMex Eclipse' have been developed for mature fruit colors at the University of New Mexico, USA. While unmature fruits are green, mature fruits turn into yellow in 'NuMex Sunrise', orange in 'NuMex Sunset' and brown in 'NuMex Eclipse' (Bosland et al., 1990). These wide range of colors allow them to be used as cut flowers.

The use of ornamental peppers as outdoor ornamental plants has increased in recent years. As an outdoor plant, ornamental peppers have a high tolerance to heat and drought and retain their vibrant bright colors throughout summer and autumn until the first frost.

A showy, colorful and decorative planting can be created in the summer heat with ornamental peppers. The diversity in size, leaf and fruit colors allow them to be used for this purpose. 'NuMex Centennial' and 'NuMex Twilight' are the most widely used varieties as outdoor ornamental plants. "NuMex Centennial" has purple flowers and purple leaves. The unmature fruit turns purple, with maturity first yellow, then orange, and finally red. 'NuMex Twilight' has white flowers and green leaves. It also has a yellow fruit color. Both varieties produce erect flowers and erect fruit at the stage of full bloom. 'NuMex Twilight' is resistant to cucumber mosaic virus (CMV) (Bosland et al., 1994).

Ornamental peppers grown as potted ornamental plants are widely sold in September, October, November and December of the year. Potted ornamental peppers; it should have characteristics such as easy propagation by seed, ripening in a short time, resistance to heat and drought and excellent fruit holding quality (Stommel & Bosland, 2006). The varieties used for this purpose are very branched and tightly developed on a stem. In addition, the fact that they have multi-colored fruits encourages their use for this purpose. Potted ornamental peppers tend to bloom continuously and produce different colored fruits at different times of the year. Small, compact, 10-15 cm tall plants bear Tabasco type fruits. If the appropriate variety is selected, the plant can be grown without the need for a growth regulator for grading control and branching. The selected varieties should also be ready for sale in a relatively short time. Irregularly spreading ornamental peppers are suitable for hanging baskets (Mavi, 2013).

While hot pepper is a very important part of the culture in the southern provinces of our country, it is more or less produced and consumed in all other provinces. In addition, especially in Hatay, in the Mediterranean and Southeastern Anatolia Regions; Chili pepper types grown in cans and pots in restaurants, tea gardens, shops and homes are frequently encountered. In addition to its direct consumption of food, pepper, which is an important species in the food industry raw material, pharmaceutical raw material and alkaloid industry, has recently appeared as a potted ornamental plant on the stalls of florists and as a decorative design plant in park and garden arrangements.

As an ornamental plant, many different types and varieties of pepper, which are ordered online by people with special interest and/or imported from abroad, have created a wide variety in our country. However, the number of varieties produced commercially as ornamental pepper is almost nonexistent. Two pickled ornamental peppers (Alpçelik and Çoşkun), which have been improved by the Batı Akdeniz Agricultural Research Institute (BATEM) in recent years, have entered the seed list in our country. However, this figure is very few when compared to hundreds of ornamental pepper varieties developed to meet very different traits and needs in the world. For this reason, we must develop our own varieties in order to meet the demands of ornamental pepper that can be used for potted flower purposes without being dependent on abroad. In particular, we do not have a type of pepper that can be used as a potted ornamental plant. This project was carried out with the basic aim of developing ornamental pepper

varieties that can be used for potted ornamental plants to meet the needs of the ornamental plant sector. In addition, within the scope of this project, it is aimed to create an ornamental pepper collection, which includes genotypes with short and narrow internodes, which can be used in later development of ornamental pepper. In the light of these explanations, the main goal of our study is to determine the suitability of some genotypes in the ornamental pepper collection of Mustafa Kemal University for potted ornamental plant cultivation and to characterize the genotypes morphologically.

MATERIAL AND METHODS

As a plant material, 16 ornamental pepper lines, which have been selected and hybridized by Kazım MAVİ since 2009, have been used. In addition, Alpçelik, one of the two ornamental pepper types registered in our country, was used as a control in the study. The experiment was carried out in an unheated glass greenhouse in Antakya district of Hatay (Turkey) between February 2017 and August 2017. Seedlings reaching the planting size were planted in pots of 18 × 16 cm size. A mixture in the form of peat, perlite prepared at a ratio of 2: 1 was used as the planting medium. The randomized block statistical design used with fifteen plants three replicates per plot in study. Plants were grown in an unheated glass greenhouse. Cultural operations during the cultivation process were carried out as reported by Kang et al. (2004).

During the trial, the maximum and minimum temperatures were determined with a digital thermometer. During the trial period, the lowest average temperatures were determined as 15.8 °C in February,

and the highest average temperatures were determined as 31.9 °C in July. It showed a steady increase in March, April, May and June (20.6, 21.7, 23.5, and 28.1 °C respectively).

The *Capsicum* descriptors of IPGRI (1995) were used for seventeen genotypes, twenty qualitative and eleven quantitative ones, observing the vegetative and reproductive characteristics of plants. For the qualitative characters related to the vegetative part, data were collected by making observations on three plants in each replication. Pomological data were determined by taking the average of ten fruits per plant for each genotype.

Quantitative characteristics were based on the mean values observed in each treatment in which the following items were evaluated plant height (pH, cm, measured from the base of the plant to the highest point of the canopy, when 50% of plants had mature fruits). Regarding the fruit characteristics, the following items were studied: 1) total number of fruits (TNF); 2) length of the fruit (LF); 3) width of the fruit (WF); 4) fruit weight (FW). For the analysis of LF, WF and FW, the means from ten randomly selected mature fruits were used. LF and WF were measured with a digital caliper, expressed in millimeters (mm). FW was equal to the mass of the fruits obtained in grams (g) carried out on an analytical balance. The qualitative characteristics were determined in 50% of the genotypes after the fruits were mature (Table 1).

Table 1: Qualitative and Quantitative Characteristics Used in the Characterization of Pepper Genotypes in the Ornamental Pepper Breeding Program of Mustafa Kemal University

Components	Descriptions
Hypocotyl colour (HC)	1= White, 2=Green, 3=Purple
Hypocotyl pubescence (HP)	3= Sparse, 5= Intermediate, 7= Dense
Cotyledonous leaf colour (CLC)	1= Light green, 2= Green, 3= Dark green, 4= Light purple, 5= Purple, 6= Dark purple, 7= Variegated, 8= Yellow, 9= Other
Cotyledonous leaf shape (CLS)	1= Deltoid, 2= Ovate, 3= Lanceolate, 4= Elong-deltoid.
Stem colour (SC)	1= Green, 2= Green with purple stribes, 3= Purple, 4= Other
Stem pubescence (SP)	3= Sparse, 5= Intermediate, 7= Dense
Plant height (PH)	Measured by tape measure (cm)
Plant growth habit (PGH)	3= Prostrate, 5= Intermediate, 7= Erect
Leaf colour (LC)	1= Yellow, 2= Light green, 3= Green, 4= Dark green, 5= Light purple, 6= Purple, 7=Variagated, 8= Other
Leaf shape (LS)	1= Deltoid, 2= Ovate, 3= Lanceolate
Leaf length (LL)	Determined by a ruler (cm)
Leaf width (LW)	Determined by a ruler (cm)
Leaf chlorophyll value (LCV)	Determined with a digital Konica SPAD chlorophyll meter
Number of flowers per axil (NFA)	1= One, 2= Two, 3= Three-five, 4= Five and more (Fasciculate), 5= Other
Flower position (FP)	3= Pendant, 5= Intermediate, 7= Erect
Corolla colour (CC)	1= White, 2= Light yellow, 3= Yellow, 4= Yelow-green, 5= Purple with white base, 6= White with purple base, 7= White with purple margin, 8= Purple 9=Yellow-green spot with white base
Corolla spot colour (CPC)	1= White, 2= Yellow, 3= Green-yellow, 4= Green, 5= Purple, 6= Other
Corolla length (CL)	Determined by a ruler (cm)
Immature fruit colour (IFC)	1= White, 2= Yellow, 3= Green, 4= Orange, 5= Purple, 6= Deep purple, 7= Other
Fruit set (FS)	The average number of fruits per plant was given as pieces
Mature fruit colour (MFC)	1= White, 2= Lemon-white, 3= Pale orange-yellow, 4= Orange-yellow, 5= Pale orange, 6= Orange, 7= Ligth red, 8= Red, 9= Dark red, 10= Purple, 11= Brown, 12= Black, 13= Other
Fruit shape (FSh)	1= Elongate, 2= Round, 3= Triangular, 4= Canpanulate, 5= Blocky, 6= Other
Length of fruit (LF)	It was measured in mm with the help of calipers. The average of 10 mature fruits in triplicate was taken.

Width of fruit (WF)	It was measured in mm with the help of calipers. The average of 10 mature fruits in triplicate was taken
Fruit weight (FW)	It is obtained by weighing the fruits one by one on a digital scale. The average of 10 ripe fruits in triplicate was taken
Fruit shape at blossom end (FSB)	1= Pointed, 2= Blunt, 3= Sunken, 4= Sunken and pointed
Fruit cross-sectional corrugation (FCC)	3= Slightly corrugated, 5= Intermediate, 7= Corrugated
Pungency (P)	Determined organoleptically
Seed colour (SC)	1= Straw, 2= Brown, 3= Black
1000-seed weight (SW)	10 seeds of 8 replicates in each genotype were weighed on a digital scale with 0.001 g precision
Number of seeds per fruit (NS)	1= Low (<20), 2= Intermediate (20-50), 3= High (>50)

The qualitative characteristics weren't analyzed. The quantitative characteristics were analyzed multivariate analysis with SPSS package programe. Means were grouped according to Duncan test. The heat map cluster and principal component analysis were composed utilizing the https://biit.cs.ut.ee/clustvis/ online program package with Euclidean distance as the similarity measure and hierarchical clustering with complete linkage (Metsalu & Vilo, 2015).

RESULTS AND DISCUSSION

Quantitative Traits

There was a significant difference for all of the quantitative traits, assessed by Duncan test ($p>0.05$) (Table 2). The average plant height of the genotypes was determined with the lowest 12.5 cm in the MKÜ-35 genotype, and the highest 76.6 cm in the MKÜ-86 genotype. Neitzke et al. (2010) reported that dwarf pepper plants should be preferred for growing in pots, and this feature is of great importance when it comes to ornamental plants, as it provides attractiveness. Similar to many

currently available ornamental pepper cultivars (Coon et al., 2017), MKÜ-4, MKÜ-35, MKÜ-44, MKÜ-73, MKÜ-84, MKÜ-97, MKÜ-101, and MKÜ-106 genotypes do not require pinching or growth regulator treatments to maintain their growth habit.

Table 2: Data and Means for Six Quantitative Traits of 17 Ornamental Pepper Genotypes in the Genetic Collection of The Department of Horticulture, Faculty of Agriculture, Mustafa Kemal University

Genotypes	PH (cm)	LL (cm)	LW (mm)	LCV	CL (cm)	FS
MKÜ-4	13.4 ij	5.61 f	2.61 ef	69.2 b	0.94 g	70 b
MKÜ-18	46.4 cd	8.96 e	4.12 c	44.3 c	2.03 a	25 def
MKÜ-19	75.0 a	11.10 a	6.69 a	51.9 c	1.20 ef	11 f
MKÜ-35	12.5 j	5.26 fg	2.57 ef	85.1 a	1.02 g	32 def
MKÜ-43	53.6 b	7.56 d	3.48 d	72.3 b	1.14 f	36 de
MKÜ-44	32.9 e	4.17 h	2.23 ef	68.8 b	1.11 f	76 b
MKÜ-71	38.0 e	10.51 ab	4.91 b	48.3 c	1.48 cd	29 def
MKÜ-73	25.4 g	5.75 f	2.75 e	78.1 ab	1.12 f	128 a
MKÜ-84	18.1 hi	6.69 e	3.31 d	67.0 b	1.00 g	64 bc
MKÜ-86	76.6 a	8.61 c	4.36 c	66.5 b	1.74 b	20 ef
MKÜ-96	47.1 c	6.62 e	3.63 d	70.5 b	1.26 e	45 cd
MKÜ-97	19.1 h	4.17 h	1.55 g	68.6 b	1.02 g	38 de
MKÜ-101	14.9 hij	4.73 gh	2.08 f	75.5 ab	1.13 f	69 b
MKÜ-106	32.7 f	5.11 fg	2.41 ef	51.1 c	1.45 cd	45 cd
MKÜ-116	46.7 cd	7.63 d	3.56 d	40.5 c	1.50 c	11 f
MKÜ-117	41.9 de	10.22 b	5.10 b	43.8 c	1.51 c	25 def
Alpçelik	42.5 cde	8.49 c	4.37 c	42.7 c	1.40 d	27 def
Avarages	37.5	7.13	3.51	61	1.29	44
CV (%)	**52**	**37**	**31**	**23**	**23**	**67**

PH =plant height; LL= leaf length; LW= leaf width; LCV= leaf chlorophyll value; CL= corolla length; FS= fruit set (number)

Table 3: Data and Means for Five Quantitative Traits of 17 Ornamental Pepper Genotypes in The Genetic Collection of The Department of Horticulture, Faculty of Agriculture, Mustafa Kemal University

Genotypes	LF (mm)	WF (mm)	FW (g)	SW	NSF
MKÜ-4	37.1 d	10.2 hi	2.29 efg	4.61 d	38 fg
MKÜ-18	35.6 de	24.1 d	9.11 c	5.19 c	67 b
MKÜ-19	31.2 def	38.1 a	8.37 c	6.14 b	64 bc
MKÜ-35	29.2 efg	14.8 f	2.95 ef	4.86 c	35 fgh
MKÜ-43	15.4 j	15.4 f	2.14 efg	3.73 f	54 cde
MKÜ-44	24.9 fgi	9.7 i	1.10 g	3.58 f	16 i
MKÜ-71	46.3 bc	20.2 e	8.15 c	4.07 e	51 de
MKÜ-73	48.1 bc	8.8 i	1.92 fg	3.01 h	33 fgh
MKÜ-84	53.6 b	8.9 i	2.40 efg	2.46 i	46 def
MKÜ-86	51.5 bc	12.8 g	4.83 d	4.97 c	43 efg
MKÜ-96	45.2 c	9.4 i	1.86 fg	3.77 f	25 hi
MKÜ-97	20.7 ij	9.0 i	0.87 g	3.33 g	17 i
MKÜ-101	23.6 gi	11.4 gh	1.53 fg	2.47 i	36 fgh
MKÜ-106	36.9 de	9.4 i	2.03 fg	3.82 f	32 gh
MKÜ-116	114.1 a	27.6 c	26.68 a	6.99 a	80 a
MKÜ-117	33.8 de	33.3 b	21.63 b	6.93 a	83 a
Alpçelik	32.3 def	14.7 f	2.29 efg	4.13 e	56 bcd
Avarages	40.0	16.3	5.97	4.30	17
CV (%)	**55**	**56**	**123**	**32**	**118**

LF= length of fruit; WF= width of fruit; FW= fruit weight; SW= 1000-seed weight; NSF= number of seeds per fruit

With the size of the fruit, the highest means ranged from 114.1 mm (MKU-116) and the lower ones varied from 15.4 mm (MKU-43) to 20.7 mm (MKU-97); for the diameter of the fruits, the highest means ranged from 33.3 mm (MKU-117) to 38.1 mm (MKU-19) and the lowest ones varied from 8.8 mm (MKU-73) to 8.9 mm (MKU-84); for fruit weight,

the highest means were between 21.63 g (MKU-117) and 26.68 g (MKU-116) and the lowest ones ranged from 0.87 g (MKU-97) to 1.10 g (MKU-44) (Table 3).

Dwarf pepper plants are more suitable for use as ornamental plants due to their upright, small and light fruits.

The coefficient of variation (CV) values ranged from 23 (LCV= leaf chlorophyll value, and CL= corolla length) to 123 (FW= fruit weight) (Table 2 and Table 3). Traits with the coefficient of variation over 30% indicate that the differences between genotypes are very high.

Qualitative Traits

Eleven genotypes (MKÜ-18, MKÜ-19, MKÜ-43, MKÜ-44, MKÜ-71, MKÜ-73, MKÜ-86, MKÜ-96, MKÜ-116, MKÜ-117, and Alpçelik) showed erect growth habit. While four genotypes showed intermediate growth habit (MKÜ-4, MKÜ-84, MKÜ-101, and MKÜ-106), two genotypes (MKÜ-35, and MKÜ-97) showed prostrate growth habit. According to Stommel & Bosland (2006), consumers prefer dwarf plants to grow in pots.

Vegetative growth in peppers is related to genetic structure, and genotypes and cultivars with short internodes gain importance in ornamental pepper breeding. The dwarf peppers are also gaining more acceptance in the ornamental plants market.

The line MKÜ-106 differs from the others especially in terms of cotyledon leaf color with it's variegate (7, mottled) color. In addition, the lines with dark violet (6) color were found to be striking (Figure 1).

Figure 1: Variation of Cotyledon Leaf Shape, Color, and Size in Ornamental Pepper Genotypes

In addition, cotyledons differ between genotypes in terms of size. It is thought that there may be a relationship between cotyledon sizes and plant sizes. It was observed that genotypes with small plant growth such as MKÜ-35, MKÜ-4, and MKÜ-84 and cotyledon sizes were also smaller than other genotypes. MKÜ-71, MKÜ-116 and MKÜ-117 have the largest cotyledon sizes.

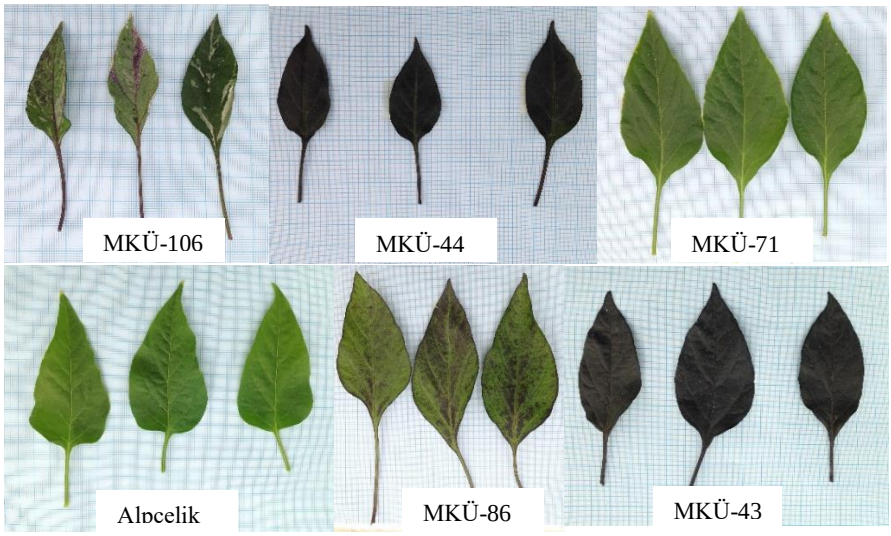

Figure 2: Examples of Leaf Shape and Color Differences (Upper row from left to right MKÜ-106, MKÜ-44, MKÜ-71, lower row from left to right Alpçelik, MKÜ-86, MKÜ-43, squares on scaled paper 1 cm)

In terms of leaf color, it has been determined that the genotypes include light green, green, dark green, light violet, violet and mottled colors. Leaf color and leaf shape, the lines have very different characteristics from the Alpçelik variety, which is used as a control. Especially in terms of leaf color, the line numbered MKÜ-106 is very different from the others with it's variegate (7, mottled) color. In addition, the lines

(MKÜ-43 and MKÜ-44) with dark violet (6) color were found to be striking (Figure 2).

Figure 3: Fruit Shapes and Color (Immature and Mature) of Ornamental Pepper Genotypes

A wide variation has been identified among the fruit shapes of the genotypes. MKÜ-84 elongate (1), MKÜ-43 round (2), MKÜ-18 triangular (3), MKÜ-19 canpanulate (4), and MKÜ-117 blocky (5) fruit-shaped genotypes (Figure 3).

There are also visible differences between the genotypes in terms of immature fruit color and mature fruit color, which are remarkable traits. Especially MKÜ-43 differs from other genotypes with its round fruits and dark purple immature fruit color. MKÜ-73 and MKÜ-96 were determined to have dark purple immature fruit color. MKÜ-106 is one of the prominent genotypes with its green-white, green-violet, mixed fruit color for ornamental plant feature (Figure 3). The Lil Pumpkin variety, one of the commercial ornamental pepper, has a blocky fruit shape (Stommel & Griesbach, 2008).

Purple color is dominant due to the accumulation of anthocyanin in flowers of genotypes (MKÜ-43, MKÜ-44, MKÜ-73, and MKÜ-86) with anthocyanin accumulation in fruits and leaves. In addition, flowers of the MKÜ-19 genotype with a species difference reflect the general characteristics of the species (Figure 4).

Figure 4: Differences in Flower Size and Corolla Color of Some of The Genotypes (Left to right, MKÜ-18, MKÜ-19, MKÜ-43, MKÜ-84 and MKÜ-86)

As a result of the principal component analysis, the first three components explained 62.1%, 12.7%, 8.2% of the variance, respectively. In other words, the total variance that can be explained as a result of principal components analysis is 82%. It is seen that leaf length, thousand seed weight, number of seeds per fruit and leaf chlorophyll value are effective in explaining PC 1. While plant height, leaf width, length of fruit, and fruit weight are effective in the formation of PC 2, only width of fruit is effective in the formation of PC 3. These quantitative traits, which are highly correlated with the basic components, have come to the fore as the traits that should be emphasized in future studies (Table 4).

Table 4: Variance, Cumulative Variance and Vector Values of the First Three Basic Components Formed As A Result Of Principal Component (PC) Analysis of Quantitative Characteristics of Ornamental Pepper Genotypes

Principal component analysis	**PC1**	**PC2**	**PC3**
Variance (%)	62.1	12.7	8.2
Cumulative variance (%)	62.1	74.8	82.0
Quantitative components			
Plant height	0.27	-0.38	-0.29
Leaf width	0.32	-0.35	-0.15
Leaf length	0.34	-0.28	-0.07
Corolla length	0.26	-0.04	-0.15
Fruit set	-0.28	-0.13	-0.07
Length of fruit	0.16	-0.62	-0.26
Width of fruit	0.34	-0.05	-0.41
Fruit weight	0.31	-0.44	-0.14
1000 seed weight	0.33	-0.17	-0.24
Number of seeds per fruit	0.34	-0.13	-0.19
Leaf chlorophyll value	-0.31	- 0.10	-0.26

Fortunato et al. (2015) reported that their parents and hybrids could be compared by examining their quantitative characteristics such as plant height, plant width, stem size, stem width, leaf size, leaf width, corolla size, petal width, anther size and style size.

A grouped data heat-map analysis of the quantitative components was carried out to show a chromatic raiting of the different ornamental pepper genotypes. The heat map analysis showed a couple of dendrograms, the first designed on the left (Dendrogram 1), an organizing that corresponded to the ornamental pepper genotypes, and the second on the top (Dendrogram 2) showing the quantitative traits that affected this distribution. Dendrogram 1 demostrated two main groups: on the top, the cluster corresponds to the MKÜ-116, MKÜ-18, MKÜ-71, Alpçelik, MKÜ-19 and MKÜ-117 genotypes, while on the down side of the heat map, the cluster includes the MKÜ-106, MKÜ-86, MKÜ-96, MKÜ-43, MKÜ-84, MKÜ-44, MKÜ-97, MKÜ-73, MKÜ-101, MKÜ-4, and MKÜ-35 ornamental pepper genotypes (Figure 5).

As seen in the dendrogram 1, genotypes are divided into 2 main groups and subgroups among themselves. Cluster 1 (up side of dendrogram 1) consisted of six different genotypes (MKÜ-116, MKÜ-18, MKÜ-71, MKÜ-19, MKÜ-117 and Alpçelik), including the control variety. When the genotypes in cluster 1 are examined carefully, it is seen that the leaf lengths are longer than the genotypes in the other cluster. Cluster 2 (downside of dendrogram 1) consists of two subgroups. The first subgroup of the cluster 2 has got MKÜ-106, MKÜ-86, and MKÜ-96.

The second subgroup of the cluster 2, except MKÜ-43, occurred from hybridized genotypes (MKÜ-4, MKÜ-73, MKÜ-84, MKÜ-97, and MKÜ-101 hybrid genotypes) and the parents of these genotypes (MKÜ-35, and MKÜ-44). The dendrogrom 1 shows that morphological characterization can be used successfully in differentiating genotypes (Figure 5).

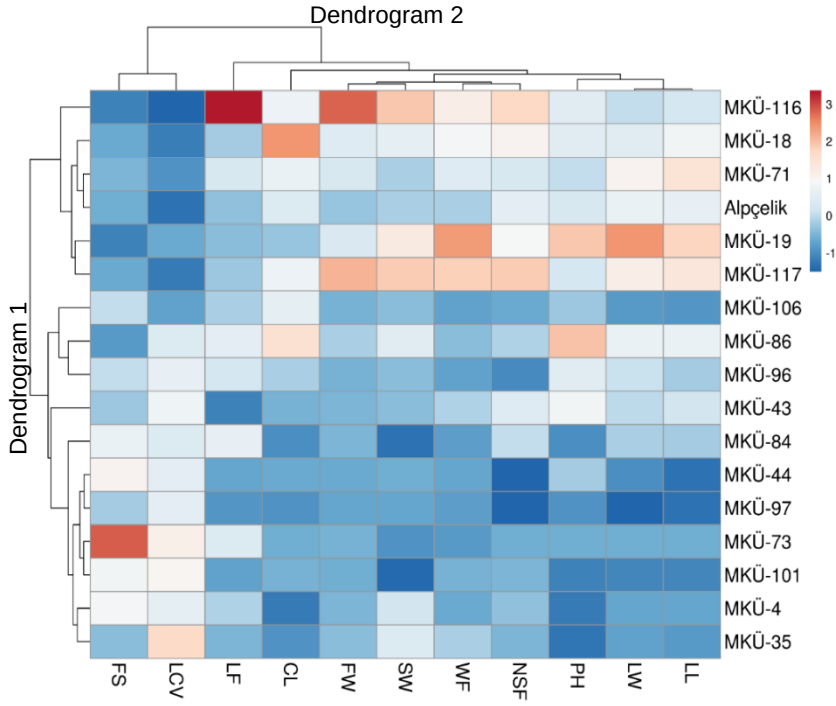

Figure 5: Cluster Heat Map Analysis Summarizing Ornamental Pepper Genotypes Responses to Quantitative Components by Using IPGR Descriptors
PH: plant height, LL: leaf length, LW: leaf width, LCV: leaf chlorophyll value, CL: corolla length, FS: fruit set, NSF: number of seeds per fruit, FW: fruit weight, LF: length of fruit, WF: width of fruit, SW: 1000 seed weight

Since MKU-19 in the cluster 1 is a genotype of *Capsicum baccatum* species, it is expected to be in a different group from other genotypes. However, the morphological characterization was insufficient at this

point. It is thought that this distinction can be clearly demonstrated by molecular characterization.

Fascinatingly, the clusters in Dendrogram 2 clearly highlight the differential influences of the different ornamental pepper genotypes (Figure 5).

The common traits of genotypes that can be used as ornamental plants is that they have short nodes. There is no quality standard developed for ornamental peppers to be used for ornamental plants in our country, However, ornamental traits are listed as plant height below 35 cm, large number of fruit per plant, medium, vertical, broad plant habitus, gradual and color-changing fruit ripening, erect fruits, spear-shaped leaves, different fruit color, and resistance to pot growing for the quality standard demanded by the market in the world ornamental plant sector. The ornamental pepper cultivars available on the commercial market are of the species *C. annuum*, and one of the genotypes (MKÜ-19) identified with potential for ornamental use is of the species *C. baccatum*. This genotype (MKÜ-19) is also used as a paternal line in the breeding program that is planned to develop a variety of the *Capsicum baccatum* species in our country (Mavi et al., 2021).

The greatest value of the genotypes, they have been determined that all ornamental pepper genotypes used in this study can be used in subsequent ornamental pepper breeding programs due to the high genetic diversity. When the results are evaluated as a whole, some genotypes of them (MKÜ-4, MKÜ-35, MKÜ-43, MKÜ-44, MKÜ-71,

MKÜ-73, MKÜ-84, MKÜ-101, and MKÜ-106) are determined that can be used as ornamental plants. Other genotypes will continue to be used in hybridization and breeding studies. Also, selection and hybridization studies are continuing to improve our ornamental pepper collection.
Last but not least, the MKÜ-84 was registered by the TTSM registration committee with the name "ÖZALKAN" at the meeting dated March 2021.

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REFERENCES

Bosland, P.W. & Votova E. (1999). Peppers: Vegetable and Spice Capsicums. CAB International, Wallingford, UK, pp: 204.

Bosland, P.W., Iglesias, J., & Gonzalez, M.M. (1994). 'NuMex Centennial' and 'NuMex Twilight' ornamental chiles. HortScience, 29(9): 1090.

Bosland, P.W., Iglesias, J., & Tanksley, S.D. (1990). 'NuMex Sunrise', 'NuMex Sunset', and 'NuMex Eclipse' ornamental chile peppers. Hortscience, 25(7): 820-821.

Coon, D., Barchenger, D.W., & Bosland, P.W. (2017). Evaluation of dwarf ornamental chile pepper cultivars for commercial greenhouse production. HortTechnology, 27: 128-131.

Fortunato, F.L.G., Rego, E.R., & Rego, M.M. (2015). Heritability and genetic parameters for size-related traits in ornamental pepper (*Capsicum annuum* L.). Acta Horticulture, 1087: 201-206.

IPGRI, (1995). Descriptor of capsicum *(Capsicum* spp.*)*. International Plant Genetic Resources Institute, Rome, Italy, pp: 51.

Kang, J., Marc, W., VanIersel, M.W., Krishna, S., & Nemali, K.S. (2004). Fertilizer concentration and irrigation method affect growth and fruiting of ornamental pepper. Journal of Plant Nutrition, 27(5): 867–884.

Mavi, K. (2013). It is a small, but huge hot taste: Ornamental pepper. Agroskop, Agust; 24-28.

Mavi, K., Hacbekir, H., Uzunoğlu, F., & Türkmen, M. (2021). The use of volatile compounds as an alternative method in pepper breeding (*Capsicum baccatum* var. *pendulum*). Ciência Rural, Santa Maria, 51(12): e20201066, doi: 10.1590/0103-8478cr20201066.

Mavi, K., Uzunoğlu, F., Eken, N. İ., Şen, Ö., Onur, A., Doksöz, S., İnceoğlu, H., & Yüceyurt, M., (2013). A study on the introduction to ornamental plants industry by different pepper genotypes. V. Ornamental Plants Congress, s: 418-422, Yalova.

Metsalu, T. & Vilo, J., (2015). Clustvis: A web tool for visualizing clustering of multivariate data using Principal Component Analysis and heatmap. Nucleic Acids Research, 43(1): 566–W570.

Neitzke, R.S., Barbieri, R.L., Rodrigues, W.F., Correa, I.V., & Carvalho, F.I.F. (2010). Genetic dissimilarity among pepper accessions with potential for ornamental use. Horticultura Brasileira, 28: 47-53.

Perry, L., Dickau, R., Zarrillo, S., Holst, I., Pearsall, D.M., Riperno, D.R., Berman, M.J., Cooke, R.G., Rademaker, K., Ranere, A.J., Raymond, J.S., Sandweiss, D.H., Scaramelli, F., Tarble, K., & Zeidler, J.A. (2007). Starch fossils and the domestication and dispersal of chili peppers (*Capsicum* spp. L.) in the Americas. Science, 315: 986–988.

Stommel J.R. & Griesbach R.J. (2008). *Capsicum annuum* L. Lil' Pumpkin™ and Pepper Jack™. Hortscience, 43(3): 935-938.

Stommel, J.R. & Bosland, P.W. (2006). Ornamental pepper. Flower Breeding and Genetics, 21: 561-599.

CHAPTER XI

Artemisia Herba Alba Asso A PLANT GROWING WILD IN ALGERIA WITH SEVERAL PHARMACOLOGICAL ACTIVITIES

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INTRODUCTION

The genus *Artemisia* L. is one of the largest genera in the Asteraceae family, consisting of more than 500 species (Abad et al., 2013).

Eleven spontaneous *Artemisia* species are present in the Algerian flora (Quezel & Santa, 1963). Among them, *Artemisia herba alba* Asso is one of the most known and used species. As seen in Figure 1, this plant is a wild aromatic shrub representing an important fodder resource in the arid pastures of the high plains regions in Algeria (Houmani et al., 2004).The species has also been extensively used in Algerian folk medicine.

Figure 1: *Artemisia herba-alba* Asso Gowing in Aïn Zaatout – Biskra Province, Algeria (Original by Messaï, 2021)

The word *Artemisia* comes from the name of the Greek goddess of the hunt Artemis, while *herba-alba* means white grass. Similarly, the name of the plant in French is armoise herbe-blanche or *armoise blanche*. In English, the plant's common name is wormwood (a name attributed to many species of the genus *Artemisia*). English etymologists have theorized that the name wormwood, comes from the bitter taste of the plant (*wermo-* is a prehistoric Germanic term for bitter) or from the plant's ancient use to treat intestinal worms (*wer-* is the Proto Indo-European source of *wyrm*, Old English for "worm") (O'Conner & Kellerman, 2018). Several other English names are attributed to the plant: Steppe thyme, desert wormwood, and white wormwood.

In North Africa and the Middle East, *Artemisia herba alba* is commonly called shih (شيح). However, it seems that in many parts of the Maghreb, the term shih is often used as a generic name for wormwood of different species, but mainly to refer to *A. herba-alba* (Gast, 2012). Since ancient times, *Artemisia herba alba* was known and used by many cultures. The plant is even mentioned in several verses of the Bible under the Hebrew name la'anah (לענה), with the implication of bitterness (Dafni & Böck, 2019).

Recent experimental studies have revealed many biological and pharmacological effects of the plant and have validated its uses in traditional medicine. The various active compounds of the plant (sesquiterpene lactones, flavonoids, and essential oils) are probably responsible for its biological and pharmacological activities.

1. BOTANICAL ASPECTS

1.1. Taxonomy

Artemisia herba-alba Asso was listed in 1779 by the Spanish botanist Ignacio Jordán Claudio de Asso y del Río (INPI, 2014). The genus *Artemisia* L. is the largest of its subtribe (Artemisiinae Less.) and tribe (Anthemideae Cass.), as well as one of the largest in the Asteraceae family. *Artemisia* has been classically divided into five subgenera. *Artemisia herba alba* belongs to the subgenus *Seriphidium* (Besser ex Less.) Rouy. From a morphological perspective, the subgenus *Seriphidium* constitutes one of the most diverse groups of *Artemisia*. Table 1 describes the current taxonomy of the plant (Malik et al., 2017; Bougoutaia, 2021).

Table 1: Taxonomy of *Artemisia herba-alba* Asso (URL-1)

Order	Asterales
Family	Asteraceae
Subfamily	Asteroideae
Tribe	Anthemideae
Subtribe	Artemisiinae
Genus:	*Artemisia*
Subgenus	*Seriphidium* (Besser ex Less.) Rouy
Species:	*Artemisia herba-alba* Asso

Artemisia herba-alba Asso is mostly diploid with a chromosome number 2n=9, and may be tetraploid with 2n=36 (Vallès et al., 2011). Within the species, four subspecies: chitachensis, kabilica, valentina

and herba-alba; and three varieties: densiflora Boiss., laxiflora Boiss., and tenuiflora Boiss., had been distinguished (Nazar & Mahmood, 2011; Vallès et al., 2011; Younsi et al., 2015).

Artemisia herba-alba Asso has been described as a Mediterranean species complex, with closely related taxa in the Irano-Turanian region included in the complex. According to recent phylogenetic studies, *Artemisia herba-alba* found mostly in the Iberian Peninsula and North-West Africa, should be considered a single species. Whereas other Irano-Turanian taxa formerly included in the complex (e.g. *A. inculta* Delile, *A. oliveriana* J.Gay ex Besser and *A. sieberi* Besser; commonly classified as synonyms of *A. herba-alba*) are estimated to be evolutionarily distant from *A. herba-alba*, and should be considered distinct species (Malik et al., 2017; Bougoutaia et al., 2021).

1.2. Morphology

Artemisia herba-alba Asso as described in the leterature (Quezel & Santa, 1963; Pottier-Alapetite, 1981; Aidoud, 1983; Akrout, 2004; Bezza et al., 2010) is a greyish perennial chaemephyte with rigid erected stems, varying in hight between 20 to 50 cm according to authors.

Leaves are small, grey, alternate, 2-3 pinnatisected, ovate, covered with glandular hairs and sessile at the flowering stage (from September to December in the Mediterranean region). Vegetative growth occurs in Autumn (large leaves), and late Winter and Spring (smaller leaves) (Figure 2).

Flower heads are small (1.5 -3 mm), ovoid, and constituted by 2-5 yellow hermaphrodite flowers. Involucral bracts are oblong with membranous margin and achenes were obovate.

Figure 2: Leaves of *Artemisia herba alba* Asso. (URL-2)

A thick woody, main root, distinct from the secondary roots, forms the subterranean part of the plant. The main root penetrates deeply into the soil up to 40 to 50 centimeters and branches only at this depth (Quezel & Santa, 1963; Pottier-Alapetite, 1981; Aidoud, 1983; Akrout, 2004; Bezza et al., 2010).

The morphological and physiological characteristics of *Artemisia herba-alba* make this species a well-adapted plant to arid climatic conditions. The seasonal dimorphism of its foliage allows it to reduce the transpiring surface and thus prevent water loss (Ourcival, 1992). Its ability to develop a fairly deep and ramified root system allows efficient water absorption (Ferchichi et al., 2004; Abderabbi et al., 2018).

1.3. Distribution

Artemisia species are distributed mainly in the northern temperate regions of the world (Abad et al., 2013). *Artemisia herba-alba* Asso is a species of steppic plants growing in arid or semi-arid lands of North Africa, the Middle East, and Spain (Mohamed et al., 2010). The plant is considered as the main forage species in chamaephytic steppes of North Africa, where it covers 10 million hectares (Bougoutaia et al., 2021) (Figure 3).

Figure 3: Global Distribution of *Artemisia herba alba* (Aidoud, 1988)

In Algeria, it presents a wide geographical distribution covering about 4 million hectares, located mainly in the steppe zone (Abderabbi et al., 2018). In an area ranging from upper semiarid to lower perarid (or Saharian) bioclimatic range. The plant mostly occurs in lime-sandy soils with 200-600 mm of mean annual precipitation (Bougoutaia et al., 2016). In these regions, in addition to its role as the main source of forage, the plant plays a natural role against erosion and desertification.

It thus contributes to the soils fixation and the preservation of steppe ecosystems (Abderabbi et al., 2018).

2. USES OF THE PLANT

2.1. Uses in Folk Medicine

Since ancient times, many cultures had used *Artemisia herba-alba* Asso as part of their traditional medicine. Generations of pastoral and nomadic populations recognize its purgative virtues. First used to flavour tea and coffee, with time, the plant became a panacea in traditional Arab and Muslim medicine (Bezza et al., 2010).

In Algerian folk medicine, this plant is used to treat various diseases and conditions: it is used as an anthelminthic, and an astringent. It is believed to be useful to stop intestinal bleeding, to treat rheumatic pains, and to cure skin diseases (Cheriti et al., 2013).

A recent ethnobotanical survey conducted in El Kantara's region (Algerian Sahara gate) showed that *Artemisia herba-alba* Asso was the most frequently used plant by the local population. The leaves were the most used part of the plant, while infusion was the most preferred form of use (Mechaala et al., 2021).

In southeastern Morocco, *Artemisia herba-alba* is among the most frequently used plants to treat diabetes and hypertension (Tahraoui et al., 2007). Infusion of the shoots of the plant is employed by the Negev Desert Bedouins to relieve stomach disorders. According to the ethnopharmacological survey conducted by Friedman et al. (1986), the

plant showed a high rank-order priority, making it considered as curative by its users.

In Jordanian traditional medicine, this plant is used as antiseptic and against skin diseases, scabies, syphilis, fever, as well as menstrual and nervous disorders (Abu-Darwish et al., 2015). In Tunisian folk medicine, the plant is known for its carminative properties. The flowers and leaves infusion is a vermifuge. The plant is used for digestive disorders, abdominal pain, and liver failure. Mixed with henna it is applied to the head to relieve neuralgia and other pain. The plant is also used to bandage wounds and to treat stomachaches (Le Floc'h, 1983; Ghrabi & Sand, 2008).

2.2. Uses in Animal Feeding

In Algeria, ranked just after halfah grass, white wormwood is considered the second most consumed species by domestic animals, mostly sheep (Bougoutaia et al., 2016). The plant is a particularly interesting forage resource; the chemical constituents and the digestibility of the plant make *A. herba alba* a forage of good feeding value (Houmani et al., 2004).

The plant has a much lower cellulose content than its appearance suggests (17-33%). The dry matter provides between 6 and 11% of raw protein. The level of β-carotene varies between 1.3 and 7 mg/kg, depending on the season.

The energy value of white Wormwood, varies depending on the season, it is low in Winter, increases rapidly in Spring, and decreases again in

Summer. In Autumn, the rains of September cause a new period of growth, and the energy value increases again (Aidoud, 1983).

2.3. Uses in Fragrance and Flavor Industries

The fragrance industry uses the essential oils extracted from *Artemisia herba alba* Asso; preferred oils by perfumers contain 30 to 35% of thujones and 34-45% of camphor. The market leader of wormwood essential oil exports is Morocco; production takes place in Marrakech, Safi, and Es-Saouira. In the flavor industry: the use of *Artemisia herba alba* essential oils is limited due to the toxicity of thujones (the maximum content in beverages is 5 mg/kg) (Vernin et al., 1995).

3. PHYTOCHEMISTRY

Several secondary metabolites have been isolated and identified from *Artemisia herba-alba* Asso, the most important of which are sesquiterpene lactones, found with great structural diversity within the genus *Artemisia.* The two other components are flavonoids, and essential oils (Marco, 1989; Mohamed et al., 2010).

3.1. Sesquiterpenes Lactones

Sesquiterpene lactones are among the compounds commonly found in Artemisia species (Sanz et al., 1990). They are largely responsible for the medicinal importance of these plants. Several sesquiterpene lactones have been identified in the aerial parts of *Artemisia herba-alba* Asso: eudesmanolides and germacranolides appear to be the most abundant types of lactones (Marco, 1989).

In a survey conducted in Israel, several different chemotypes of *Artemisia herba-alba* Asso were identified based on the nature of their sesquiterpene lactones (Segal et al., 1987).

Phytochemical studies of *Artemisia herba-alba* growing in Spain (Gomis et al., 1979; Sanz & Marco, 1991) and Egypt (Ahmed et al., 1990), identified sesquiterpenes lactones that are completely different from those previously isolated from plants growing in Israel. Other studies in Morocco (Marco et al., 1994) and Algeria (Vernin et al., 1995) confirmed the richness of the genus *Artemisia* in sesquiterpenes.

In 2008, phytochemical investigation of the aerial parts of *Artemisia herba-alba* growing in Tebessa (East of Algeria), lead to the isolation of two new natural sesquiterpene lactones: 1b,9b-diacetoxyeudesm-3-en-5a,6b,11bH-12,6-olide (1) and 1b,9b-diacetoxyeudesm-4-en-6b,11bH-12,6-olide (2) (Messai et al., 2008).

3.2. Phenolic Compounds and Flavonoids

Various phenolic compounds were isolated from *Artemisia herba alba*. Kim et al. (2004) isolated eight polyphenols and related components in a study of *Artemisia herba-alba* Asso's antiulcerogenic active ingredients. Chlorogenic acid was isolated from *Artemisia herba* growing in Morocco (Mouhajir et al., 2001).

The flavonoids detected in *Artemisia herba-alba* Asso show structural diversity, ranging from common flavonoids (flavones glycosides and flavonols) to methylated flavonoids which are very unusual.

Glycoside flavonoids include O-glycosides such as quercitin-3-glucoside and C-glycosides flavones that are rare in the genus Artemisia, as well as in all Asteraceae (Saleh et al., 1987; Salah & Jäger, 2005).

In studies of *Artemisia herba-alba* Asso collected from Sinai (Egypt), a total of eight flavonoids O-and C-glycosides were isolated and identified (Saleh et al., 1985; Saleh et al., 1987). The study of the aerial portions of *Artemisia herba-alba* Asso collected in Lebanon led to the isolation of two flavonoids: hispidulin and cirsilineol (Salah & Jäger, 2005).

3.3. Essential Oils

Hydrodistillation of *Artemisia herba-alba* arial parts produces a bright yellow essential oil with an intense woody smell (Aloui et al., 2016). Reports on oil yields indicate a range of [0.1 to 4.9% (v/w), with the highest yields obtained at the flowering phase (Belhattab et al., 2014). Extracted essential oils show great chemodiversity, not only between plants growing in different countries but also between plants growing in different localities in the same country (Salido et al., 2004; Paolini et al., 2010). Furthermore, the chemical variability of the extracted essential oils depends on the nature of the used botanical part of the plant (Tilaoui et al., 2015).

Table 2: Main components of the essential oils of *Artemisia herba-alba* Asso growing in Algeria

Main Components	Region	Reference
Chrysanthenone (4.1-54.5%), α -thujone (3.7-27.6%), β-thujone (4.1-15.6%), camphor 6-15.9%, bornyl acetate (0.1- 8.1%), cineole (1.5-5.7%).	Bibans (Bordj Bou Arreridj) at various periods of the growing cycle of the plants.	Boutekedjiret et al., (1992)
Camphor (19-48%), α-thujone (1.0-26.7%), chrysanthenone (5-22.5%), 1,8-cineole (5-20%), β-thujone (1.65-9.3%), camphene (1.7-7.9%), cineole (5-20%).	Various areas of Algeria: Bou Saada, Batna, Sidi Aissa, Djelfa and Kenchela.	Vernin et al., (1995)
Camphor (19.4%), trans-pinocarveol (16.9%), chrysanthenone (15.8%) and β-thujone (15%).	Djebel Messâd (M'sila).	Dob & Benabdelkader, (2006)
Depending on the extraction method (hydrodistillation - microwave distillation, (49.3 and 48.1%), 1,8-cineole (13.4-12.4%), borneol (7.3-7.1%), pinocarvone (5.6-5.5%), camphene (4.9-4.5%) and chrysanthenone (3.2-3.3%).	Boussaada.	Dahmani-Hamzaoui & Baaliouamer, (2010)
Cis-chrysanthenyl acetate (25,12%), α -thujone (7,85 %), 2E,3Z-2-ethyliden-6-methyl-3,5-heptadienal (8,39%), verbenone (7,19%), myrtenyl acetate (7,39 %), chrysanthenone (4,98 %).	Baniane (Biskra).	Bezza et al., (2010)
Three main components : camphor (17-33%), α -thujone (7-28%) and chrysanthenone (4-19%). Despite the similarity in main components, three types of oils could be defined, (a) α -thujone : camphor (23-28: 17-28%), (b) camphor : chrysanthenone (33:12%) (c) α -thujone : camphor : chrysanthenone (24:19:19%)	Different localities in Algeria (Benifouda; Bougaa; Boussaada and Boutaleb), characterized by diverse geographic and climate conditions.	(Belhattab et al., 2014)

In most cases, it has been reported that *Artemisia herba-alba* oil contains mainly monoterpenoids, mainly oxygenated, such as 1,8-cineole (Feuerstein et al., 1986), chrysanthenone, chrysanthenol (and its acetate), -thujone and camphor (Feuerstein et al., 1988).

Studies of essential oil composition extracted from plants growing in six different countries (Algeria, Egypt, Jordan, Morocco, Spain, Tunisia) showed that all countries report the presence of, α -thujone and β -thujone. While chrysantenone, camphor and 1,8-cineole occurrencies was always mentioned in, at least, some studies (Belhattab et al., 2014).

Similarly, essential oils of *Artemisia herba alba* growing wild in Algeria show a composition variability according to the region, the used part of the plant, the period of harvesting, and the method of extraction. Table 2 shows a compilation of essential oil composition reported by different Algerian studies.

4. PHARMACOLOGICAL ACTIVITIES

Studies have reported several biological and pharmacological activities of *Artemisia herba alba*. For many of these pharmacological activities, the precise underlying mechanism (s) of action remain to be determined.

4.1. Hypoglycaemic and Antidiabetic Effects

In normal fasted rats, the oral administration of 0.39 g/kg body weight of the aqueous extract of *Artemisia herba alba* leaves produces a significant hypoglycaemic effect (Alkhazraji et al., 1994). The hypoglycaemic effect of the aqueous extract of *Artemisia herba alba* is also effective in diabetic rats receiving the same dose of the extract (Tastekin et al., 2006). The significant hypoglycaemic effect is produced within 2 hours of the oral administration, and is comparable

with that of repaglinide and insulin (Tastekin et al., 2006). Still using diabetic rats, the oral administration of 300 mg/kg body weight of the aqueous infusions of *A. herba-alba* in alloxan-induced diabetic rats shows a much more efficient antidiabetic activity compared to glibenclamide, the oral hypoglycaemic agent used as a positive control (Boudjelal et al., 2015).

Besides the hypoglycemic effect provided by *Artemisia herba alba*, diabetic rats can experience other health benefits of the plant as shown by the study conducted by Al-Shamaony et al. (1994). In this study, diabetic rats and rabbits received for 2-4 weeks 0.39 g/kg body weight of the aqueous extract of the aerial parts of the plant. Results showed a significant reduction in blood glucose level, prevention of the elevation of glycosylated haemoglobin levels, and a hypoliposis effect of the extract, Results showed also a protective effect against body weight loss of diabetic animals (Al-Shamaony et al., 1994).

The antidiabetic effect of *Artemisia herba alba* is also beneficial in type 2 diabetes.

An Algerian study evaluated the preventive effect of the hydro-alcoholic extracts of *Artemisia herba-alba* Asso, in a model of type 2 diabetes induced by a high fat-diet in diabetes-prone mice (Hamza et al., 2010). At the end of the study (20 weeks), groups treated with Artemisia extracts showed a significant reduction in mean fasting blood glucose, triglyceride concentrations, and serum insulin levels. The plant

extracts also markedly reduced insulin resistance as measured by the homeostasis model assessment (Hamza et al., 2010).

4.2. Antioxidant Activity

In a study conducted by Djeridane et al. (2006), for the assessment of the antioxidant activity of phenolic compounds of certain Algerian medicinal plants, *Artemisia herba-alba* Asso, found to exhibit a strong antioxidant activity. In Tunisia, Khlifi et al. (2013) used three different in vitro assays (i.e., DPPH/ABTS radical scavenging and AAPH) to assess the antioxidant activity of the methanolic extracts of local *Artemisia herba-alba* plants; results showed high antioxidant activity. The antioxidant effect of *Artemisia herba-alba* is particularly beneficial in alloxan-induced diabetic rats. The plant's aqueous extract supplementation reduces alloxan-induced free radical generation, potentiates the antioxidant defense system, and alleviates renal sensitivity to oxidative stress (Sekiou et al., 2021).

Ben Abid et al. (2007) compared the long-term effects of *Artemisia herba-alba* Asso decoction with a green or black tea decoction. Artemisia as well as green tea decoctions increased the total antioxidant status, whole blood glutathione peroxidase activity, and the status of zinc and copper. The beneficial antioxidant effects were in descending order: artemisia decoction > or = green tea decoction > black tea decoction (Ben Abid et al., 2007).

4.3. Anti-inflammatory, Antipyretic, and Analgesic Activities

The ethanolic extract of *Artemisia herba alba* showed an anti-inflammatory effect in carrageenan-induced paw edema in rats, and an analgesic effect against acetic acid-induced writhing (Abdel Jaleel et al., 2016).

Similarly, the aqueous extract of the plant showed anti-inflammatory and antinociceptive effects. The observed effects of the aqueous extract are considerably related to the presence of astragalin and eupatilin that were isolated from the aerial parts of *Artemisia herba alba* (Qnais et al., 2014).

Using Brewer's yeast model of pyrexia (Abdel Jaleel et al., 2016) demonstrated that *Artemisia herba-alba* ethanolic extract exhibits antipyretic effects comparable to paracetamol.

4.4. Gastroprotective Activity

The plant extract showed gastroprotective activity against ethanol-induced gastric ulcers. Administration of the extract at the doses of 100, 200, and 400 mg/kg decreased the number of ulcers and reduced ulcer severity by respectively 82%, 76% and 79%, compared to group pretreated with standard ranitidine (95%) (Abdel Jaleel et al., 2016).

The gastroprotective effects of aqueous leaves extract of *Artemisia herba alba* Asso is also effective against aspirin-induced gastric lesion in male albino rats. The oral administration of the extract before aspirin

led to gastric protection detected by a decrease in both ulcers number and gastric fluid contents (Abushwereb & Tolba, 2016).

4.5. Hypotensive Activity

In normal rats, the intravenous bolus injection of *Artemisia herba alba* aqueous extracts at different doses of 50, 100, and 200 mg/kg produces a dose-dependent reduction in arterial blood pressure. A significant reduction in heart frequency was observed after a 100 and 200 mg/kg injection (Ali Zeggwagh et al., 2014). According to a study conducted by Skiker et al. (2011). *Artemisia herba alba* aqueous extract produces an endothelium-dependent relaxation of the isolated rat aorta.

4.6. Diuretic Activity

Artemisia herba alba perfusion may affect renal function to increase urine and electrolytes excretion with no effect on glomerular filtration rate. Perfusion of aqueous extract of the plant at a dose of 200 mg/(kg·h) causes a significant increase in urine output after 4 hours of perfusion, and a significant increase in urinary sodium, potassium and chlorure excretion (Ali Zeggwagh et al., 2014).

4.7. Antileishmania Activity

Regarding the antileishmania activity of *Artemisia herba alba*, Hatimi et al. (2001) demonstrated that both the aqueous extract and the essential oil of the plant have leishmanicidal activity against two species of Leishmania: *Leishmania tropica* and *Leishmania major*. The strongest leishmanicidal activity was observed with the essential oil at

2 micrograms/ml, while the aqueous extract showed an antileshmanial activity at 4 micrograms/ml.

Artemisia herba alba essential oil is also active against *Leishmania infantum.* The observed antileishmanial activity was mediated by cell apoptosis induction and cell cycle arrest at the sub-G0/G1 phase (Aloui et al., 2016).

4.8. Antifungal Activity

Essential oil of *Artemisia herba alba* growing in Algeria is effective against three species of yeast (*Candida albicans*, *Candida stellatoidae* and *Candida tropicalis*), and four species of fungi (*Microsporom canis*, *Microsporom gypseum*, *Trichophyton interdigitale* and *Aspergillus terrus* (Charchari et al., 1996).

The antifungal activity of *Artemisia herba alba* against *Penicillium citrinum* and *Mucora rouxii* is associated with two major volatile compounds isolated from the fresh leaves of the plant: carvone and piperitone (Saleh et al., 2006).

4.9. Anticancer Activity

Studies show promising anticancer activity of *Artemisia herba alba*, in various cancer cell lines and tumors. Methanolic extracts from Tunisian *Artemisia herba-alba*, showed a high anticancer activity against several cell lines: human bladder carcinoma RT112 (IC50 = 81.59 ± 4.4 mg/L); human laryngeal carcinoma Hep2 (IC50 =59.05 ± 3.66 mg/L) and human myelogenous leukemia (IC50 =90.96 mg/L). The anticancer

activity was correlated with the phenolic contents of the extracts (Khlifi et al., 2013).

Moroccan *Artemisia herba alba* essential oil showed also a significant antiproliferative activity against the acute lymphoblastic leukaemia (CEM) cell line, (IC50 = 3 μg/mL) (Tilaoui et al., 2011). Exposure of HCT116 human colon cancer cells to *Artemisia herba-alba* ethanol extract decreases cell viability, causes DNA damage, and induces apoptosis via the activation of caspase-3 and increase in Bax and p53 proteins. While the aqueous extract had no antineoplastic effects (Lupidi et al., 2011).

Oral administration of *Artemisia herba alba* crude extract (300 mg/kg) caused a significant reduction in the mortality rate of mice bearing Ehrlich solid carcinoma tumor. After 10 days of treatment, mortality rate was 30% in Artemisia group versus 77% in the control one. This effect was better than the commercially used anticancer drug cisplatin, which reduced the mortality rate to only 60 % after ten days of its administration (Hanan et al., 2018).

4.10. Antibacterial Activity

Bertella et al. (2018) investigated the *in vitro* antibacterial activity of essential oil of *Artemisia herba-alba* growing Batna (Algeria). Disc diffusion assays concerned 21 bacterial strains. Results showed an important effect against *Staphylococcus aureus* MRSAB2, *Acinetobacter baumannii* ABB2, *Staphylococcus aureus* MRSAB3, *Staphylococcus aureus* MRSAB1, *Acinetobacter baumannii* ABB1,

and *Klebsiella oxytoca* KOB1. While *Pseudomonas aeruginosa* PAA1 was highly resistant. The antibacterial activities of *A. herba-alba* essential oil were in some cases very similar to streptomycin and in others lower (Bertella et al., 2018).

The methanolic extract of the arial parts of *Artemisia herba alba* collected in Kairouan-Tunisia, showed also an antibacterial activity against Gram positive and Gram negative bacteria (Younsi et al., 2015).

4.11. Anthelmintic Activity

Seddiek et al. (2011) compared the effect of crude aqueous extracts of *Artemisia herba alba*, and Albendazole a broad-spectrum antihelminthic, against *Heterakis gallinarum* infecting turkey poults. Results demonstrated that seven days post-treatment, both Albendazole and Artemisia extract reduced egg output (97.31 and 97.78%, respectively), and worm burden of *H. gallinarum* (95.08 and 96.07%, respectively). The herbal extract improved significantly feed conversion ratio compared to the other infected groups (positive control and Albendazole treated group) and had no adverse effect on the liver and kidney of treated poults.

Ahmed et al. (2020) investigated the *in vitro* anthelmintic efficacy of crude methanolic extracts of *Artemisia herba-alba* against *Haemonchus contortus*, one of the most pathogenic nematodes of ruminants. The crude extracts of *A. herba-alba* exhibited anthelmintic activity at all dose levels in a concentration and time-dependent fashion (Ahmed et al., 2020).

4.12. Antispasmodic Activities

Artemisia herba-alba essential oil possesses a significant inhibition effect on jejunum contractions as shown by Yashphe et al. (1987). In another study, the essential oil from the plant's aerial parts collected in Morocco reversibly relaxed the spontaneous tonus of the rabbit jejunum in a reversible concentration dependent manner. Authors validated the use of this herbal medicine for the treatment of gastrointestinal spasms (Aziz et al., 2012).

CONCLUSION

Artemisia herba alba Asso, is one of the most used wild-growing plants in Algeria. Generations of pastoral and nomadic populations consider it as a valuable forage source and a beneficial medicinal plant. Similarly, in many other countries where the plant is found, *Artemisia herba alba* Asso is part of the local traditional pharmacopeia.

Several studies have investigated the chemical composition and pharmacological activities of this plant. Results of the phytochemical studies revealed the presence of many active compounds, while the experimental studies revealed many biological and therapeutical activities. Nevertheless, the precise underlying mechanism(s) of the revealed effects remain to be determined. Hence, the need to undertake more studies, to valorize this popular medicinal plant into the health care system.

REFERENCES

Abad, M.J., Bedoya, L.M., & Bermejo, P. (2013). Essential Oils from the Asteraceae Family Active against Multidrug-Resistant Bacteria. In: Fighting Multidrug Resistance with Herbal Extracts, Essential Oils and Their Components, Academic Press, pp: 205–221.

Abdel Jaleel, G.A.R., Abdallah, H.M.I., & Gomaa, N.E.L.S. (2016). Pharmacological effects of ethanol extract of Egyptian *Artemisia herba-alba* in rats and mice. Asian Pacific Journal of Tropical Biomedicine, 6(1): 44–49.

Abderabbi, K., Adda, A., Benhassaini, H., & Merah, O. (2018). Leaf morphological and anatomical traits variation of *Artemisia herba-alba* in a steppe zone of Algeria. Bulgarian Journal of Agricultural Science, 24(4): 631-637.

Abu-Darwish, M.S., Cabral, C., Gonçalves, M.J., Cavaleiro, C., Cruz, M.T, Efferth, T., & Salgueiro, L. (2015). *Artemisia herba-alba* essential oil from Buseirah (South Jordan): Chemical characterization and assessment of safe antifungal and anti-inflammatory doses. Journal of Ethnopharmacology, 174: 153-160.

Abushwereb, H. & Tolba, M. (2016). Gastroprotective activity of *Artemisia herba alba* aqueous extract on aspirin-induced gastric lesions in albino rats. Journal of Pharmaceutical and Applied Chemistry, 3: 1-11.

Ahmed, A.A., Abou-El-Ela, M., Jakupovic, J., Seif El-Din, A.A., & Sabri, N. (1990). Eudesmanolides and other constituents from *Artemisia herba-alba.* Phytochemistry, 29(11): 3661-3663.

Ahmed, A.H., Mebrat, E., Teka, F., Dereje, R., Bahar, M., Solomon, A.H. (2020). In vitro anthelmintic activity of crude extracts of *Artemisia herba-alba* and *Punica granatum* against *Haemonchus contortus*. Journal of Parasitology Research, pp: 7.

Aidoud, A. (1983). Contribution à l'étude des écosystèmes steppiques du Sud oranais: Phytomasse, productivité primaire et applications pastorales. Thèse doct. 3°cycle. USTHB. Alger. pp: 180.

Aidoud, A. (1988). Les écosystèmes à Armoise blanche (*Artemisia herba-alba*. Asso.), I : Caractères généraux. Bulletin d'écologie terrestre (Biocénoses), 3: 1-15.

Akrout, A. (2004). Etude des huiles essentielles de quelques plantes pastorales de la région de Matmata (Tunisie). In : Ferchichi A. (comp.), Ferchichi A. (collab.). Réhabilitation des pâturages et des parcours en milieux méditerranéens. Zaragoza : CIHEAM, pp: 289-292 (Cahiers Options Méditerranéennes; n. 62).

Ali Zeggwagh, N., Michel, J.B., & Eddouks, M. (2014). Acute hypotensive and diuretic activities of *Artemisia herba alba* aqueous extract in normal rats. Asian Pacific Journal of Tropical Biomedicine, 4(2): 644-648.

Alkhazraji, S., Al-Shamaony, L., & Twaij, H. (1994). Hypoglycaemic effect of *Artemisia herba alba*. I. Effect of different parts and influence of the solvent on hypoglycaemic activity. Journal of ethnopharmacology, 40: 163-6.

Aloui, Z., Messaoud, C., Haoues, M., Neffati, N., Bassoumi Jamoussi, I., Essafi-Benkhadir, K., Boussaid, M., Guizani, I., & Karoui, H. (2016). Asteraceae *Artemisia campestris* and *Artemisia herba-alba* essential oils trigger apoptosis and cell cycle arrest in leishmania infantum promastigotes. Evidence-Based Complementary and Alternative Medicine, pp: 15.

Al-Shamaony, L., Al-Khazraji, S.M., & Twaij, H.A. (1994). Hypoglycaemic effect of *Artemisia herba alba.* II. Effect of a valuable extract on some blood parameters in diabetic animals. Journal of Ethnopharmacology, 43(3): 167-171.

Aziz, M., Karim, A., El Ouariachi, E., Bouyanzer, A., Amrani, S., Mekhfi, H., Ziyyat, A., Melhaoui, A., Bnouham, M., & Legssyer, A. (2012). Relaxant effect of essential oil of *Artemisia herba-alba* Asso on rodent jejunum contractions. Scientia Pharmaceutica, 80(2): 457-467.

Belhattab, R., Amor, L., Barroso, J.G., Pedro, L.G., & Figueiredo, A.C. (2014). Essential oil from *Artemisia herba-alba* Asso grown wild in Algeria: Variability assessment and comparison with an updated literature survey. Arabian Journal of Chemistry, 7(2): 243-251.

Ben Abid, Z., Feki, M., Hédhili, A., & Hamdaoui, M.H. (2007). *Artemisia herba-alba* Asso (Asteraceae) has equivalent effects to green and black tea decoctions on

antioxidant processes and some metabolic parameters in rats. Annals of Nutrition and Metabolism, 51(3): 216-622.

Bertella, A., Benlahcen, K., Abouamama, S., Pinto, D., Maamar, K., Mebrouk, K., Silva, A. (2018). *Artemisia herba-alba* Asso. Essential oil antibacterial activity and acute toxicity. Industrial Crops and Products, 116: 137-143.

Bezza, L., Mannarino, A., Fattarsi, K., Mikail, C., Abou, L., Hadji-Minaglou, F., & Kaloustian, J. (2010). Chemical composition of the essential oils of *Artemisia herba-alba* issued from the district of Biskra (Algeria). Phytothérapie, 8: 277–281.

Boudjelal, A., Siracusa, L., Henchiri, C., Sarri, M., Abderrahim, B., Baali, F., & Ruberto, G. (2015). Antidiabetic effects of aqueous infusions of *Artemisia herba-alba* and *Ajuga iva* in Alloxan-Induced Diabetic Rats. Planta Medica, 81(9): 696-704.

Bougoutaia, Y., Garcia, S., Garnatje, T., Kaid-Harche, M., & Vallès, J. (2016). Genome size, chromosome number, and rDNA organisation in Algerian populations of *Artemisia herba-alba* (Asteraceae), a basic plant for animal feeding facing overgrazing erosion. Anales del Jardín Botánico de Madrid, 73(2): e043.

Bougoutaia, Y., Garnatje, T., Vallès, J., Kaid-Harche, M., Ouhammou, A., Dahia, M., Tlili, A., & Vitales, D. (2021). Phylogeographical and cytogeographical history of *Artemisia herba-alba* (Asteraceae) in the Iberian Peninsula and North Africa: mirrored intricate patterns on both sides of the Mediterranean Sea. Botanical Journal of the Linnean Society, 195(4): 588–605.

Boutekedjiret, C., Charchari, S., Belabbes, R., & Bessière, J.M. (1992). Contribution à l'étude de la composition chimique de l'huile essentielle *d'Artemisia herba-alba* Asso. Rivista Italiana EPPOS, 3: 39-42.

Charchari, S., Dahoun, A., Bachi, F., & Benslimani, A. (1996). Antimicrobial activity in vitro of essential oils of *Artemisia herba-alba* Asso and *Artemisia judaica* L. from Algeria. Rivista Italiana EPPOS, 18: 3-6.

Cheriti, A. Belboukhari, N., & Hacini, S. (2013). Ethnopharmacological survey and phytochemical screening of some medicinal Asteraceae from Algerian Sahara. Phyto Chem & BioSub Journal, 7(2): 52-56.

Dafni, A. & Böck, B. (2019). Medicinal plants of the Bible-revisited. Journal of Ethnobiology Ethnomedicine, 15: 57.

Dahmani-Hamzaoui, N. & Baaliouamer, A. (2010). Chemical Composition of Algerian Artemisia herba-alba Essential Oils Isolated by Microwave and Hydrodistillation. Journal of Essential Oil Research, 22(6): 514-517.

Djeridane, A., Yousfi, M., Nadjemi, B., Boutassouna, D., Stocker, P., & Vidal, N. (2006). Antioxidant activity of some Algerian medicinal plants extracts containing phenolic compounds. Food Chemistry, 97: 654-660.

Dob, T. & Benabdelkader, T. (2006). Chemical Composition of the Essential Oil of *Artemisia herba-alba* Asso Grown in Algeria. Journal of Essential Oil Research, 18: 685-690.

Ferchichi, A., Chaieb, C., & Ferjani, E. (2004). Caractérisation de la variabilité du comportement phycologique de certaines populations d'*Artemisia herba-alba* du sud Tunisien. CIHEAMIAMZ, (Cahiers Option Méditerranéennes; 62: 489.

Feuerstein, I., Danin, A., & Segal, R. (1988). Constitution of the essential oil from an *Artemisia herba-alba* population of Spain. Phytochemistry, 27(2): 433-434.

Feuerstein, I., Müller, D., Hobert, K., Danin, A., & Segal, R. (1986). The constitution of essential oils from *Artemisia herba-alba* populations of Israel and Sinai. Phytochemistry, 25(10): 2343-2347.

Friedman, J., Yaniv, Z., Dafni, A., & Palewitch, D. (1986). A preliminary classification of the healing potential of medicinal plants, based on a rational analysis of an ethnopharmacological field survey among Bedouins in the Negev desert, Israel. Journal of Ethnopharmacology, 16(2-3): 275-87.

Gast, M. (2012). Armoise. In: Encyclopédie berbère [En ligne], 6 1989, document A273, mis en ligne le 01 décembre 2012, consulté le 08 août 2021. URL : http://journals.openedition.org/encyclopedieberbere/2592.

Ghrabi, Z. & Sand, R. L. (2008). *Artemisia herba alba* Asso. In A Guide to Medicinal Plants in North Africa. IUCN Centre for Mediterranean Cooperation, Malaga, Spain, 49-49.

Gomis, J.D., Marco, J.A., Llinares, J. R. P., Parareda, J.S., Sendra, J.M., & Seoane, E. (1979). Sesquiterpene lactones, waxes and volatile compounds from *Artemisia herba-alba* subspecies valentina. Phytochemistry, 18: 1523-1525.

Hamza, N., Berké, B., Cheze, C., Agli, A., Robinson, P., Gin, H., & Moore, N. (2010). Prevention of type 2 diabetes induced by high fat diet in the C57BL/6J mouse by two medicinal plants used in traditional treatment of diabetes in the east of Algeria. Journal of ethnopharmacology, 128: 513-518.

Hanan, R.H., Mohamed, M.A., El Faky, A.S.A. (2018). Evaluating the effect of oral administration of *Artemisia herba alba* extract compared to artesunate on the mortality rate of ehrlich solid carcinoma bearing mice. International Journal of Science and Research, 7(6): 579-581.

Hatimi, S., Boudouma, M., Bichichi, M., Chaib, N., Idrissi, N.G. (2001). In vitro evaluation of antileishmania activity of *Artemisia herba alba* Asso. Bulletin de la Société de Pathologie Exotique, 94(1): 29-31.

Houmani, M., Houmani, Z., & Skoula, M. (2004). Intérêt de *Artemisia herba-alba* Asso. dans l'alimentation du bétail des steppes algériennes. Acta Botanica Gallica, 2: 165-172.

INPI., (2014). Inventaire National du Patrimoine Naturel. https://inpn.mnhn.fr/ espece/cd_nom/83978/tab/taxo

Khlifi, D., Sghaier, R. M., Amouri, S., Laouini, D., Hamdi, M., & Bouajila, J. (2013). Composition and anti-oxidant, anti-cancer and anti-inflammatory activities of *Artemisia herba-alba, Ruta chalpensis* L., and *Peganum harmala* L. Food and Chemical Toxicology, 55: 202-208.

Kim, T.H., Ito, H., Hatano, T., Taniguchi, S., Khennouf, S., & Yoshida, T. (2004). Chemical constituents of *Artemisia herba-alba* Asso. Natural Medicines, 58(4): 165.

Le Floc'h, E. (1983). Contribution à une étude ethnobotanique de la flore tunisienne. Imprimerie officielle de la République Tunisienne, Tunis.

Lupidi, G., Bramucci, M., Quassinti, L., Fornari, E., Avenali, L., Khalife, H., & Gali-Muhtasib, H. (2011). Antiproliferative activities of *Artemisia herba-alba* ethanolic extract in human colon cancer cell line (HCT116). Alternative Medicine Studies, 1:e14.

Malik, S., Vitales, D., Qasim Hayat, M., Korobkov, A. A., Garnatje, T. & Vallès, J. (2017). Phylogeny and biogeography of *Artemisia* subgenus *Seriphidium* (Asteraceae: Anthemideae). Taxon, 66: 934-952.

Marco, J.A. (1989). Sesquiterpene lactones from *Artemisia herba-alba.* Phytochemistry, 28: 3121-3126.

Marco, J.A., Sanz-Cervera, J.F., & Ocete, G. (1994). New germacranolides and Eudesmanolides from North African *Artemisia herba-alba.* Journal of Natural Products, 57(7): 939-946.

Mechaala, S., Bouatrous, Y., Adouane, S. (2021). Traditional knowledge and diversity of wild medicinal plants in El Kantara's area (Algerian Sahara gate): An ethnobotany survey. Acta Ecologica Sinica, 10.1016/j.chnaes.

Messai, L., Hegazy, M.E., Ahmed, A.B., Ali, K., Belkacemi, D., & Ohta, S. (2008). Sesquiterpene lactones from Algerian *Artemisia herba-alba.* Phytochemistry Letters, 1: 85-88.

Mohamed, A.H.H., El-Sayed, M.A., Hegazy, M.E., Helaly, S.E., Esmail, A.M., & Mohamed, N.S. (2010). Chemical constituents and biological activities of *Artemisia herba-alba.* Records of Natural Products, 4(1): 1-25.

Mouhajir, F., Pedersen, J.A., Rejdali, M., & Touer, S.G.H.N. (2001). Phenolics in Moroccan medicinal plant species as studied by electron spin resorance spectroscopy. Pharmaceutical Biology, 39(5): 391-398.

Nazar, N. & Mahmood, T. (2011). Morphological and molecular characterization of selected *Artemisia* species from Rawalakot, Azad Jammu and Kashmir. Acta Physiologiae Plantarum, 33: 625-633.

O'Conner, P.T. & Kellerman, S. (2018). The bitterness of wormwood. In Grammarphobia: Grammar, etymology, usage, and more. https://www .grammarphobia.com/blog/2018/01/wormwood.html.

Ourcival, J.M. (1992). Réponses de Deux Chaméphytes de la Tunisie Présaharienne à Différentes Contraintes et Perturbations. Doctoral Dissertation, Montpellier 2.

Paolini, J., El Ouariachi, E.M., Bouyanzer, A., Hammouti, B., Desjobert, J.M., Costa, J., & Muselli, A. (2010). Chemical variability of *Artemisia herba-alba* Asso essential oils from East Morocco. Chemical Papers, 64 (5): 550-556.

Pottier-Alapetite, G. (1981). Flore de la Tunisie: Angiospermes, Dicotylédones, Gamopétales. Imprimerie officielle de la république Tunisienne, Tunisia,; pp: 1190.

Qnais, E., Raad, D., & Bseiso, Y. (2014). Analgesic and anti-inflammatory effects of an extract and flavonoids from *Artemisia herba-alba* and their mechanisms of action. Neurophysiology, 46: 238-246.

Quezel, P. & Santa, S. (1963). Nouvelle flore de l'Algérie et des régions désertiques méridionales. Éditions du Centre National de la Recherche Scientifique. Paris, Tome I. pp: 565.

Salah, S.M. & Jäger, A.K. (2005). Two flavonoids from *Artemisia herba-alba* Asso with in vitro GABAa-benzodiazepine receptor activity. Journal of Ethopharmacology, 99: 145.

Saleh, M.A., Belal, M.H., & El-Baroty, G. (2006). Fungicidal activity of *Artemisia herba alba* Asso (Asteraceae). Journal of Environmental Science and Health, Part B, 41(3): 237-244.

Saleh, N.A. M., El-Negoumy, S.I., & Abou-Zaid, M.M. (1987). Flavonoids of *Artemisia judaica, A. monosperma* and *A. herba-alba.* Phytochemistry, 26(11): 3059-3064.

Saleh, N.A.M., El-Negoumy, S.I., Abd-Alla, M.F., Abou-Zaid, M.M., Dellamonica, G., & Chopin, J. (1985). Flavonoids glycosides of *Artemisia monosperma* and *A. herba-alba.* Phytochemistry, 24 (1): 201-203.

Salido, S., Valenzuela, L.R., Altarejos, J., Nogueras, M., Sanchez, A., & Cano, E. (2004). Composition and infraspecific variability of *Artemisia herba-alba* from southern Spain. Biochemical Systematics and Ecology, 32: 265-277.

Sanz, J.F. & Marco, J.A. (1991). New eudesmanolide related to Torrentin from *Artemisia herba-alba* subsp. Valentine. Planta Medica, 57: 74-76.

Sanz, J.F., Castellano, G., & Marco, J. A. (1990). Sesquiterpene lactones from *Artemisia herba-alba.* Phytochemistry, 29(2): 541-545.

Seddiek, S.A., Ali, M.M., Khater, H.F., & El-Shorbagy, M.M. (2011). Anthelmintic activity of the white wormwood, *Artemisia herba-alba* against *Heterakis gallinarum* infecting turkey poults. Journal of Medicinal Plants Research, 5(16): 3946-3957.

Segal, R., Feuersteint, I., & Danin, A. (1987). Chemotypes of *Artemisia herba-alba* in Israel Based on Their sesquiterpene lactone and essential oil constitution. Biochemical SysternatYcs and Ecology, 15(4): 411-416.

Sekiou, O., Boumendjel, M., Taibi, F., Tichati, L., Boumendjel, A., Messarah, M. (2021). Nephroprotective effect of *Artemisia herba alba* aqueous extract in alloxan-induced diabetic rats. Journal of Traditional and Complementary Medicine, 11(1): 53-61.

Skiker, M., Mekhfi, H., Aziz, M., Haloui, B., Lahlou, S., Legssyer, A., Bnouham, M., & Ziyyat, A. (2011). *Artemisia herba-alba* Asso relaxes the rat aorta through activation of NO/cGMP pathway and K(ATP) channels. Journal of Smooth Muscle Research, 46(3): 165-74.

Tahraoui, A., El-Hilaly, J., Israili, Z.H., & Lyoussi, B. (2007). Ethnopharmacological survey of plants used in the traditional treatment of hypertension and diabetes in south-eastern Morocco (Errachidia province). Journal of Ethnopharmacology, 110(1): 105-117.

Tastekin, D., Atasever, M., Adigüzel, G., Keles, M., & Tastekin, A. (2006). Hypoglycaemic effect of *Artemisia herba-alba* in experimental hyperglycaemic rats. Bulletin of the Veterinary Institute in Pulawy, 50: 235-238.

Tilaoui, M., Ait Mouse, H., Jaafari, A., & Zyad, A. (2015). Comparative phytochemical analysis of essential oils from different biological parts of *Artemisia herba alba* and their cytotoxic effect on cancer cells. PLoS One, 10(7): e0131799.

Tilaoui, M., Ait Mouse, H., Jaafari, A., Aboufatima, R., Chait, A., & Zyad, A. (2011). Chemical composition and antiproliferative activity of essential oil from aerial parts of a medicinal herb *Artemisia herba-alba*. Revista Brasileira Farmacognosia, 21(4): 781-785.

Vallès, J., Garcia, S., Hidalgo, O., Martín, J., Pellicer, J., Sanz, M., & Garnatje, T. (2011). Biology, genome evolution, biotechnological issues and research including applied perspectives in Artemisia (Asteraceae). Advances in Botanical Research, 349–419.

Vernin, G., Merad, O., Vernin, G. M., Zamkotsian, R.M., & Parkanyi, C.D. (1995). GC/MS analysis of *Artemisia herba-alba* Asso essential oils from Algeria. Development in Food Sciences, 37: 147-205.

Yashphe, J., Feuerstein, I., Barel, S., & Segal, R. (1987). The antibacterial and antispasmodic activity of *Artemisia herba alba* Asso. II. examination of essential oils from various chemotypes. International Journal of Crude Drug Research, 25(2): 89-96.

Younsi, F., Trimech, R., Abdennacer, B., Olfa, E., Dhahri, S., Boussaid, M., & Messaoud, C. (2015). Essential oil and phenolic compounds of *Artemisia herba-alba* (Asso.): Composition, antioxidant, antiacetylcholinesterase, and antibacterial activities. International Journal of Food Properties, 19(7): 1425-1438.

URL-1: https://www.ncbi.nlm.nih.gov/Taxonomy (Acces date: 20.09.2021)

URL-2:https://www.florealpes.com/fiche_armoiseblanche.php. (Access date: 01.09.2021)

CHAPTER XII

RESPONSE OF YIELD AND FRUIT QUALITY OF PROCESSING TOMATOES TO DEFICIT IRRIGATION PRACTIES

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INTRODUCTION

Tomato is included in the Solanaceae family in which there are more than 3000 species with economic importance (Bergougnoux, 2014). It is not known where it was initially cultivated. It is estimated that the tomato plant cropped up in Peru or Mexico from among South American countries, and brought to Europe in 16th century (Gould, 1992).

Tomato is one of the vegetables that is being produced the most in the world. In addition, it is the most consumed vegetable following potato. In 2019, tomato ranked the eight crop with a production amount of 180 million tons following sugar cane, corn, rice, potato, wheat, soybean and manioc (FAOSTAT, 2021).

Tomato, which is grown at field and greenhouse, has a great richness of cultivar. Due to its high adaptation ability, it is produced and consumed at many locations both in northern and southern hemispheres (Abak, 2016).

The main production zones of tomato are located at mild climate areas close to 40th parallel in northern and southern hemispheres. But a great majority of production is performed at northern hemisphere where 90% of crops in the world are being processed (Anonymous, 2021a; Figure 1).

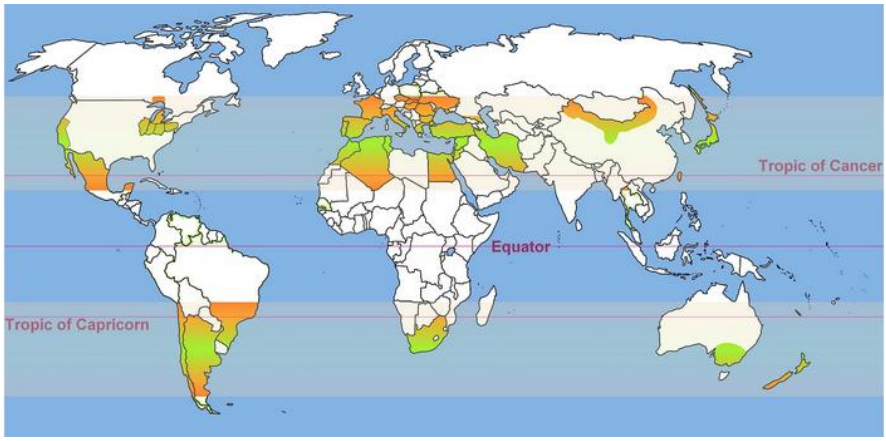

Figure 1: Main Production Regions of Tomato in the World (Anonymous, 2021a)

Today, while about 78% of tomatoes produced in the whole world are consumed as fresh, the remaining 22% of them are used in the preparation of paste, ketchup, mash, soup, dried tomato, fruit juices, pickle and sauces in tomato processing industry (WPTC, 2021).

For the consumers who don't have access to fresh consumption, processed tomato products have become a significant nutritional source. In recent years, the consumption of processed tomato products has increased along with the increasing population and urbanization (Anonymous, 2021b). In the market, there are various processed tomato products appealing to different palate and preferences of the consumers. The history of tomato processing industry dates back to 1847. The processing of tomato for the first time in history started with the production of canned tomatoes in Pennsylvania in 1847 by Harrison Woodhull Crosby (Gould, 1992).

If we summarize the history and development of processing tomato;

- Canned tomato was initially produced in 1847.
- Canned tomato was manually produced until 1890s.
- Between years 1890-1900, scalded and peeled tomato products started to be used.
- By the beginning of 1920s, fruit juice was developed, and started to take its place at the groceries.
- In 1930s, homogenization and flash pasteurization methods were used in the processing of tomato juice, and significant progress was made on it.
- In 1940s, stewed tomatoes were started to be used.
- In 1950s, lye peeling and flame peeling methods significantly contributed to processing tomato industry.
- In 1960s, the use of acid and flavoring substances was permitted as food additive in canned tomatoes.
- By the end of 1960s, mechanical harvest started to be used. Moreover, new various tomato products such as diced, quartered, crushed, stewed, sliced, frozen sliced tomatoes, and tomato cocktail juices in many styles were put on the market.
- In 1970s, tomato sauces and pizza sauces started to be produced.
- In 1980s, it was started to obtain tomato juices from tomato concentrate, and it became a significant product (Gould, 1992).

In 2020, global tomato processing industry reached a volume of about 40 million tons (WPTC, 2021; Anonymous, 2021b; Figure 2).

Figure 2: Global Processing Tomato Production in 2020 (million mT; Anonymous, 2021c)

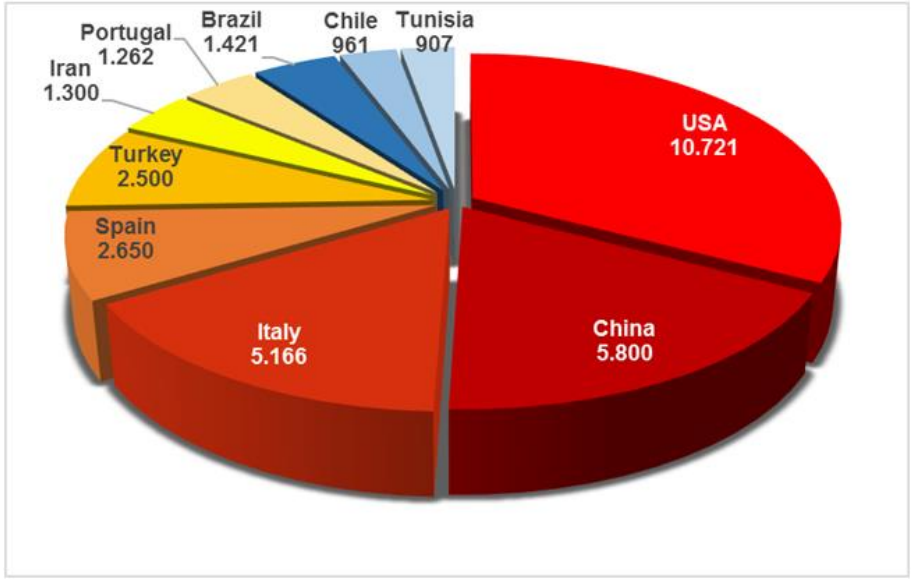

Figure 3: Processing Tomato Production by Top 10 Countries (million mT)

Despite tomato processing industry is present in many countries, USA, China, Italy, Spain, Turkey, Iran, Portugal, Brazil, Algeria and Tunisia are the top 10 countries in the world where tomato is processed. These countries constitute 83% of the total production in the world (WPTC, 2021; Figure 3). In addition, the amount of tomato products processed in other countries except the referred ones is steadily increasing in recent years, and the share of top 10 in global activity is tending to decrease.

In tomato processing industry, the product range increased compared to past, and tomato products are being processed and consumed in many countries. In 2019-2020, 13 countries (USA, China, 7 in the EU, Turkey, Iran, Ukraine, and Chile), that are the main tomato producers, exported 6.8 million tons of tomato paste, canned tomato, tomato sauces, and ketchup. Considering these products, tomato paste was exported as 3.4 million tons, canned tomato as 1.9 million tons, and tomato sauces and ketchup as 1.5 million tons. Especially tomato paste forms the main item of processing tomato products in terms of both production volume, and commercial value. In 2018-2019, more than 3.1 billion dollars of 6.4 billion dollars, obtained from the export of tomato products, was obtained by tomato paste (Anonymous, 2021d).

The tomato cultivars used in tomato processing industry consist of processing tomato cultivars. The obtainment of required level of yield and quality raw material in processing tomato cultivation depends on cultivation practices such as irrigation, fertilization, management of diseases and pests, and management of weed as well as selection of

suitable cultivars. Irrigation is the most significant cultivation practice. The deficient or incorrect practice of irrigation directly affects the yield and fruit quality in the production of processing tomato.

Today, the increasing population and urbanization at arid and subarid areas has increased the requirement for water. For this reason, great changes are required in irrigation management in order to increase the usage performance of water allocated for agriculture (Kirda, 2002).
The changing soil cultivation practices, and agronomic measures such as mulching may decrease the demand for irrigation water. In addition, another option is deficit irrigation practices. Deficit irrigation practices are ones performed by exposing the plants to specific levels of water stress during a specific growth period, or along the whole growth season without having significant decrease in yield (Kirda, 2002). Its main purpose is to increase the water usage efficiency of plants by decreasing the surplus irrigation that has a very few effect on yield. Thus both water saving is ensured, and required level of yield and quality products are obtained. Moreover, the decrease in yield caused by deficit irrigation practices is much lower than decrease in yield caused by disease and pests, losses during harvest and storage, and insufficient fertilizer applications (Kirda, 2002).

Water is in the state of scarce source not only for arid and subarid areas, but also for areas where precipitation rate is high. Irrigated farming constitutes 70% of water usage in the world, and water and energy consumption are linked to each other (Pardo Picazo et al., 2018;

WWAP, 2021). For this reason, effective use of water resources is important.

The aim of this section is to focus on the effects of deficit irrigation practices, which became widespread today, on the yield and fruit quality in processing tomato cultivation.

1. DEFICIT IRRIGATION

The concept of deficit irrigation was initially used in 1970 (Capra et al., 2008). Deficit irrigation is an irrigation strategy in which net return is maximized by decreasing the amount of irrigation water applied on agricultural products to a specific level (Capra et al., 2008).
Today, regulated deficit irrigation (RDI), and partial root drying (PRD) are extensively used deficit irrigation methods.

RDI is the irrigation performed under the required irrigation amount for the optimal plant growth. By this method, water deficit is allowed at a specific level, and the amount of water used in the irrigation of crops is decreased (Chai, 2016). By decreasing the amount of water applied at specific periods, it is ensured for the plant to be affected at minimum, and to have minimum level of yield loss (Ouda, 2020). RDI is successfully used in the cultivation of fruits and vegetables (Domingo et al., 1996; Gonzá Lez-Altozano & Castel, 1999; Pérez-Pérez et al., 2009; Coyago-Cruz et al., 2019; Lu et al., 2019; Vélez-Sánchez et al., 2021). When RDI technique is used, the size of fruit and vegetative growth may be kept under control. In addition, water saving is ensured, and fruit quality at required level is obtained (Capra et al., 2008).

Partial root drying (PRD) is another extensively used irrigation method just like RDI. In PRD method, while half of the plant's root system is fully irrigated, the other half is left dry (Chai et al., 2018). In order to prevent drying of the roots, the wet and dry parts are changed in rotation (Jovanovic & Stikic, 2018). When this method is used, significant rate of water saving is ensured. Moreover, vegetative growth may be kept under control, and fruit quality is positively affected. While the method is providing advantage by these aspects, it is disadvantageous due to the high installation cost, and lack of its effect on the fruit size (Capra et al., 2008).

1.1. Researches into Deficit Irrigation Practices on Yield and Fruit Quality in Processing Tomato

Many studies were conducted regarding deficit irrigation practices in the cultivation of processing tomato. In the studies performed, it was searched whether it is possible to obtain high yield and fruit quality or not by ensuring water saving.

In a research conducted in California, Mitchell et al. (1991) searched the effects on yield and fruit quality of restriction of irrigation water, and irrigation with saline drainage water in the cultivation of processing tomato. In the research, UC82B processing tomato cultivar was used. By the results obtained from the study, they reported that restriction of water was decreasing the yield and amount of fruit juice, but that it was increasing the amounts of brix, citric acid, hexose, and potassium. Moreover, they reported that the application of water on irrigation water

was not causing any loss in yield, and that it was decreasing the amount of fruit juice.

Prieto et al. (1999) searched the effects on yield and fruit quality of sprinkling, furrow and drip irrigation methods in the cultivation of processing tomato in Spain along two production seasons. They reported that in the case when water requirement was fully met more yield was obtained by drip irrigation and sprinkling practices compared to furrow irrigation. Moreover, they specified that when water restriction was applied by the drip irrigation method both water saving was ensured, and the brix was increasing significantly.

Renquist & Reid (2001) investigated the effects of different irrigation regimes on the yield and fruit quality of processing tomato. The research was conducted in New Zealand, and Cannery Row processing tomato cultivar was used. In the research, 4 different irrigation practices (SC: standard commercial regime, with late cut-off; DE: early deficit irrigation, also with late cut-off; FS: full season irrigation at the SC rate, with no cut-off, and DL: late deficit irrigation, during final fruit growth and ripening, essentially an early irrigation cut-off) were tested. By the end of the study, it was specified that the reddening rate of fruits at the time of harvest was changing at the rate of 97% by the DL practice, and at the range of 89-93% in other practices. But they reported that the yield was obtained as 38% lower due to obtainment of 35% lower size fruits in the DL practice. Similarly, it was reported that pH value of fruits was found the best (lower) in DL practice. They reported that while the fruit quality parameters (total solids, soluble solids

concentration (SSC) and titratable acidity) were similar in SC, DE and FS practices, the highest results were obtained by the DL practice.

Marouelli et al. (2004) studied the effects on yield and fruit quality of 14 different cut off irrigation practices by 7 days intervals from blossom to harvest in the cultivation of processing tomato at Cerrado area in Brazil. They specified that brix was decreasing with a value of 0.34 in each ten days. Moreover, they reported that the maximum pulp yield (28º brix) was obtained from the practice in which the irrigation was stopped 34 days before the harvest, and maximum marketable fruit yield was obtained from the practice in which the irrigation was stopped 21 days before the harvest.

Zegbe et al. (2004) searched the effects on yield and fruit quality of PRD method in the cultivation of processing tomato. By the end of the study, it was reported that PRD practice was not affecting the total yield and fruit weight. Moreover, it was specified that the fruits were better coloring, and that the brix was increasing by PRD.

Johnstone et al. (2005) examined the effects on yield and brix of deficit irrigation practices on 8 processing tomato cultivars (Halley, Heinz 9494, Hypeel 303, HM 830, AB2, Peto 849, Heinz 9665, and Heinz 9663) at 6 different plot where the soil texture were different (loam, clay, silty clay loam, clay loam, sandy loam, and sandy clay loam). The research was conducted in California along 4 production seasons by the use of drip irrigation method. In the research, the irrigation practice in which the irrigation was being cut off 40-50 days before the harvest (by

the beginning of ripening), and the irrigation practice, that the farmers of the area extensively use, in which it was being cut off 20 days preharvest were compared. By the end of the study, they reported that yield was decreasing in the irrigation practice in which irrigation was being cut off 40-50 days preharvest, but that the brix values were being obtained higher than the standard practice (the irrigation practice in which irrigation was being cut off 20 days preharvest).

In another study conducted in California by Quadir et al. (2005), they specified that the deficit irrigation practice was performed in the period when the fruits began to redden in the cultivation of processing tomato, and that it increased the brix without significant level of loss in yield values.

Zegbe et al. (2007) investigated the effects on biomass, plant growth, yield, and fruit quality of full irrigation, PRD, and deficit irrigation (DI) in Petopride processing tomato cultivar. By the end of the study, they reported that the fruit weight was obtained low by the DI practice. On the other hand, they reported that the brix value of fruits was obtained high both by PRD and DI. Moreover, it was specified that color of fruit, and amount of fruit juice was similar in all three practices. They specified that the PRD practice will be more advantageous compared to DI practice at areas where water resources are scarce.

Favati et al. (2009) examined the effects on yield and fruit quality of decrease of irrigation water until harvest during two production seasons in the cultivation of Ability processing tomato cultivar. By the end of

the study, they reported that lycopene, vitamin C and brix were increasing along with yield.

Patane & Cosentino (2010) searched the effects on yield and fruit quality of 6 different irrigation practices in the cultivation of processing tomato at two areas in Sicily where soil and climate characteristics were different. In the research, 6 different irrigation practices as being no irrigation after plant establishment (NI), long-season full irrigation (LF), long-season deficit irrigation (LD), short-season full irrigation up to first fruit set (SF), and short-season deficit irrigation up to first fruit set (SD), and land forming–drainage (LFD) were tested. By the end of the study, they reported that the best results were obtained by the LFD practice in both areas in terms of amount of marketable fruits, fruit weight, brix, and yield.

Giuliani et al. (2011) asserted that the preservation of water resources and efficient use of water in cultivation performed at wide areas and for obtainment of high yield may only be possible by the practice of water restriction under a specific program.

Battilani et al. (2012) reported that that plant's water consumption varied between 400-800 mm in the period as from planting until harvest in the cultivation of processing tomato. They reported that the amount of water consumed in that period changed depending on the cultivar, climate, soil structure, and irrigation program. In addition, they specified that furrow irrigation is extensively being used today, but that deficit irrigation practices are being used in production at wide areas.

Moreover, they reported that it is being stuck upon deficit irrigation in recent years due to obtainment of water saving, maintainig yield and quality products by deficit irrigation practices.

Helyes et al. (2012) searched the effects on antioxidant compounds (lycopene, phenolic compounds, and ascorbic acid) and yield in tomato fruits on which water stress was created by regular irrigation until harvest, and cut off irrigation 30 days preharvest in cultivation of processing tomato. They reported that regular irrigation until harvest increased the yield and ascorbic acid amount of tomato fruits. But they specified that the lycopene and brix contents of fruits grown by regular irrigation were found to be lower.

Nardella et al. (2012) examined effects on processing tomato of deficit irrigation practices in South Italy. In the research, three different irrigation practices as being deficit irrigation (70DI: 70% ETc), Partial Root-zone Drying (70PRD: 70% ETc), and full irrigation (FI: 100% ETc) were tested. By the results of the study, they reported that lower stomatal conductance values were obtained by two deficit irrigation practices (DI, and PRD), and that significant rate of water saving was ensured by the preservation of marketable yield. Moreover, they specified that PRD method indicated a bit higher water use efficiency (WUE) compared to DI. In addition, they specified that yield response factor (Ky) indicated values smaller than one.

Helyes et al. (2014) evaluated the effects on yield parameters (yield, and brix values), and antioxidant contents (carotenoids, polyphenol,

and tocopherol concentration) of irrigation in cultivation of processing tomato. The study was conducted in Hungary by the use of Brixsol F1 and Strombolino F1 cultivars along two production seasons. The researchers reported that the yield was increasing, but the antioxidant content of the cultivars was decreasing along with the increase of irrigation.

In the study conducted by Zhang et al. (2014), they specified that in case of practice of water restriction on processing tomato grown at arid lands that the economic gain would decrease between 11.3%-45.3% compared to full irrigation.

Patanè & Saita (2015) examined the effects on fruit yield and biomass of water restriction in processing tomato grown under subarid Mediterranean climate. In the research, 3 different irrigation programs (no irrigation, 100% full irrigation, 50% irrigation) were tested at two different plots having 2.5 plants (P1), and 5 plants (P2) per square meter. It was specified that the dry weight and yield was found to be high by rates of 36%, and 33% for two years at plot P2 compared to plot P1. In addition, they determined that water restriction practiced at plot P2 ensured water saving by more than 45% compared to full irrigation, and that the fruit quality increased compared to full irrigation.

Giuliani et al. (2016) searched the effects on yield and fruit quality of DI and RDI irrigation methods in processing tomato grown under subarid conditions in Italy. In the study, Genius F1 tomato cultivar was

used. In the research, 5 different practices as being minimum irrigation (I_0), deficit irrigation only during planting and fertilization, regulated deficit irrigation (RDI-ETc %60), full irrigation during the three main phenological periods of tomato (ETc %60-%80-%60), and farmer irrigation were tested. The researchers specified that RDI strategy was increasing the fruit quality, and it was ensuring water saving at a rate of 27%. Moreover, in cultivation of processing tomato grown under Mediterranean climate, they suggested the referred method due to obtainment of water saving both during the vegetative and ripening stages.

Barrios-Masias & Jackson (2016) conducted a research on whether the PRD technique may be an alternative of furrow irrigation in the cultivation of processing tomato in California. The study was conducted during two production seasons, and on three different soil types. In the research, growth of plant, leaf gas change, fruit quality, and humidity of soil were examined. By the end of the study, they reported that fresh yields were maintained, and fruit quality was preserved by the PRD technique. Moreover, they specified that more than 29% water productivity was ensured by the PRD technique. The researchers specified that sustainable production in agriculture may be ensured by the use of PRD technique compared to furrow irrigation at areas where water resources are low.

Lu et al. (2019) reviewed 25 articles in the meta analysis performed for examining the effects on yield and fruit quality of RDI practice in processing tomato. By the end of the study, it was specified that the fruit

yield decreased approximately by 18.61 t ha^{-1}, but water use efficiency (WUE) increased by 2.33 kg m^{-3}. Moreover, they specified that fruit quality increased by the RDI practice. Similarly, they specified that RDI practice may improve brix and vitamin C contents in the cultivation of processing tomato, and that it ensured increase in brix and vitamin C values when applied in the third stage (abbreviated as R stage) compared to the other two stages (as V stage, and abbreviated as F stage).

Valcárcel et al. (2020) investigated the effects on processing tomato of controlled deficit irrigation (CDI) practices. In the study conducted in Spain, 3 different irrigation practices (100% ETc, 75% ETc CDI, 50% ETc CDI) were tested on 4 different processing tomato cultivars (H-9036, H-9661, H-9997, and ISI-24424). They reported that while 26.1% water saving was ensured, the yield decreased by 10.7% in 75% ETc CDI practice. On the other hand, they specified that while 13% water saving was ensured, the yield was not affected in the 50% ETc CDI practice. The researchers reported that the effect on fructose, glucose, citric and glutamic acid amounts of deficit irrigation practice was insignificant, but that it decreased the malic acid amount.

CONCLUSION

Tomato is a summer vegetable, and its water requirement during the cultivation period is high. The cultivars of processing tomato are significant raw materials for the industry, and their economic return is high. The obtainment of required fruit quality will only be possible by the modern agriculture techniques.

Irrigation is one of the most important cultivation practices in agricultural production. Ensuring the benefit expected from irrigation depends on amount of water used, time of irrigation, and manner of practice. Deficit irrigation practices are among the modern agriculture techniques used today by the benefits they provide. Deficit irrigation practices intend to obtain maximum level of income by decreasing the amount of irrigation water. During practices, the plant is exposed to water stress, and a specific level of decrease occurs in yield. But the fruit quality is generally affected positively. It requires technological infrastructure, and knowledge. When it is practiced correctly, yield is maintained, and required level of fruit quality is obtained. By the deficit irrigation practices in cultivation of processing tomato, required level of raw materials are able to be obtained.

When deficit irrigation in cultivation of processing tomato is practiced at the right time and at sufficient amount considering the climate and soil structure, quality fruits having required characteristics will be able to be obtained as well as maintaining the yield in the cultivars grown.

REFERENCES

Abak, K. (2016). Past, present and future of tomato in Turkey. Journal of Turkish Seed Growers Association, 17: 8-13.

Anonymous, (2021a). http://www.tomatonews.com/en/background_47.html (Access date: 18.05.2021).

Anonymous, (2021b). http://www.tomatonews.com/en/worldwide-consumption-of-tomato-products-20182019-part-1_2_994.html (Access date: 21.06.2021).

Anonymous, (2021c). http://www.tomatonews.com/maj/phototheque/photos/WorldProd_2020_2.jpg (Access date: 18.05.2021).

Anonymous, (2021d). http://www.tomatonews.com/en/background_47.html (Access date: 19.05.2021).

Barrios-Masias, F.H., & Jackson, L.E. (2016). Increasing the effective use of water in processing tomatoes through alternate furrow irrigation without a yield decrease. Agricultural Water Management, 177: 107-117.

Battilani, A., Prieto, M.H., Argerich, C., Campillo, C., & Cantore, V. (2012). Tomato. Crop yield response to water. In. FAO Irrigation and Drainage Paper 66. (Eds. Steduto, P., Hsiao, T.C., Fereres, E., & Raes, D.) Rome, Italy, Food and Agriculture Organization of the United Nations. pp: 174-180.

Bergougnoux, V. (2014). The history of tomato: from domestication to biopharming. Biotechnology Advances, 32(1): 170-189.

Capra, A., Consoli, S., & Scicolone, B. (2008). Deficit Irrigation: Theory and Practice. Agricultural Irrigation Research Progress, Nova Science Pub., USA, pp: 53-82.

Chai, Q., Gan, Y., Zhao, C., Xu, H.L., Waskom, R.M., Niu, Y., & Siddique, K.H. (2016). Regulated deficit irrigation for crop production under drought stress. A review. Agronomy for Sustainable Development, 36(1): 1-21

Coyago-Cruz, E., Meléndez-Martínez, A.J., Moriana, A., Girón, I.F., Martín-Palomo, M.J., Galindo, A., ... & Corell, M. (2019). Yield response to regulated deficit irrigation of greenhouse cherry tomatoes. Agricultural Water Management, 213: 212-221.

Domingo, R., Ruiz-Sánchez, M. C., Sánchez-Blanco, M. J., & Torrecillas, A. (1996). Water relations, growth and yield of Fino lemon trees under regulated deficit irrigation. Irrigation Science, 16(3): 115-123.

FAOSTAT, (2021). http://www.fao.org/faostat/en/#home (Access date: 20.05.2021).

Favati, F., Lovelli, S., Galgano, F., Miccolis, V., Di Tommaso, T., & Candido, V. (2009). Processing tomato quality as affected by irrigation scheduling. Scientia Horticulturae, 122(4): 562-571.

Giuliani, M.M., Gatta, G., Nardella, E., & Tarantino, E. (2016). Water saving strategies assessment on processing tomato cultivated in Mediterranean Region. Italian Journal of Agronomy, 11(1): 69-76.

Giuliani, M.M., Nardella, E., Gatta, G., De Caro, A., & Quitadamo, M. (2011). Processing tomato cultivated under water deficıt conditions: The effect of azoxystrobin. Acta Hortic., 914: 287-294.

Gonzá Lez-Altozano, P. & Castel, J.R. (1999) Regulated deficit irrigation in`Clementina de Nules' citrus trees. I. yield and fruit quality effects. The Journal of Horticultural Science and Biotechnology, 74(6): 706-713.

Gould, W.A. (1992). Tomato Production, Processing and Technology. Third Edition. Elsevier. ISBN 0-930027-18-3. Worthington, Ohio.

Helyes, L., Lugasi, A., & Pek, Z. (2012). Effect of irrigation on processing tomato yield and antioxidant components. Turkish Journal of Agriculture and Forestry, 36(6): 702-709.

Helyes, L., Lugasi, A., Daood, H. G., & Zoltán, P.É.K. (2014). The simultaneous effect of water supply and genotype on yield quantity, antioxidants content and composition of processing tomatoes. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 42(1): 143-149.

Johnstone, P.R., Hartz, T.K., LeStrange, M., Nunez, J.J., & Miyao, E.M. (2005). Managing fruit soluble solids with late-season deficit irrigation in drip-irrigated processing tomato production. HortScience, 40(6): 1857-1861.

Jovanovic, Z. & Stikic, R. (2018). Partial root-zone drying technique: from water saving to the improvement of a fruit quality. Frontiers in Sustainable Food Systems, Volume 1:3, p. 1-9

Kirda, C. (2002). Deficit irrigation scheduling based on plant growth stages showing water stress tolerance. Food and Agricultural Organization of the United Nations, Deficit Irrigation Practices, Water Reports, 22(102).

Lu, J., Shao, G., Cui, J., Wang, X., & Keabetswe, L. (2019). Yield, fruit quality and water use efficiency of tomato for processing under regulated deficit irrigation: A meta-analysis. Agricultural Water Management, 222: 301-312.

Marouelli, W.A., Silva, W.L., & Moretti, C.L. (2004). Production, quality and water use efficiency of processing tomato as affected by the final irrigation timing. Horticultura Brasileira, 22(2): 226-231.

Mitchell, J.P., Shennan, C., Grattan, S.R., & May, D.M. (1991). Tomato fruit yields and quality under water deficit and salinity. Journal of the American Society for Horticultural Science, 116(2): 215-221.

Nardella, E., Giuliani, M.M., Gatta, G., & De Caro, A. (2012). Yield response to deficit irrigation and partial root-zone drying in processing tomato (*Lycopersicon esculentum* Mill.). Journal of Agricultural Science and Technology. A, 2(2A): 209-219.

Ouda, S., Noreldin, T., & Zohry, A.E.H. (2020). Vegetable Crops and Deficit Irrigation in Egypt. In: Deficit Irrigation. Springer, Cham. https://doi.org/10.1007/978-3-030-35586-9_5

Pardo Picazo, M.Á., Juárez, J.M., & García-Márquez, D. (2018). Energy consumption optimization in irrigation networks supplied by a standalone direct pumping photovoltaic system. Sustainability, 10(11): 4203.

Patanè, C. & Cosentino, S.L. (2010). Effects of soil water deficit on yield and quality of processing tomato under a Mediterranean climate. Agricultural Water Management, 97(1): 131-138.

Patanè, C. & Saita, A. (2015). Biomass, fruit yield, water productivity and quality response of processing tomato to plant density and deficit irrigation under a semi-arid Mediterranean climate. Crop and Pasture Science, 66(2): 224-234.

Pérez-Pérez, J.G., Robles, J.M., & Botía, P. (2009). Influence of deficit irrigation in phase III of fruit growth on fruit quality in 'Lane Late' sweet orange. Agricultural Water Management, 96(6): 969-974.

Prieto, M.H., López, J., Ballesteros, R., & Junta de Extremadura, S.I.A. (1999). Influence of irrigation system and strategy on the agronomic and quality parameters of the processing tomato in extremadura. Acta Hortic., 487: 575-579.

Quadir, M., Hickey, M., Boulton A., & Hoogers, R. (2005). Effect of deficit irrigation on tss in tomatoes. IREC Farmers' Newsletter, 172: 36-37.

Renquist, A.R. & Reid, J.B. (2001). Processing tomato fruit quality: Influence of soil water deficits at flowering and ripening. Australian Journal of Agricultural Research, 52(8): 793-867

Valcárcel, M., Lahoz, I., Campillo, C., Martí, R., Leiva-Brondo, M., Roselló, S., & Cebolla-Cornejo, J. (2020). Controlled deficit irrigation as a water-saving strategy for processing tomato. Scientia Horticulturae, 261, 108972.

Vélez-Sánchez, J.E., Balaguera-López, H.E., & Alvarez-Herrera, J.G. (2021). Effect of regulated deficit irrigation (RDI) on the production and quality of pear Triunfo de Viena variety under tropical conditions. Scientia Horticulturae, 278, 109880.

WPTC, (2021). http://www.wptc.to/releases-wptc.php (Access date: 18.05.2021)

WWAP, (2021). United Nations World Water Assessment Programme. The United Nations World Water Development Report 2014: Water and Energy; UNESCO: Paris, France, 2014.

Zegbe, J. A., Behboudian, M. H., & Clothier, B. E. (2007). Response of tomato to partial rootzone drying and deficit irrigation. Revista Fitotecnia Mexicana, 30(2): 125-131.

Zegbe, J.A., Behboudian, M.H., & Clothier, B.E. (2004). Partial rootzone drying is a feasible option for irrigating processing tomatoes. Agricultural Water Management, 68(3): 195-206.

Zhang, H.J., Wen, A.C., & Zhang, J.D. (2014). Effect of regulated deficit irrigation on water use and economic benefit of processing tomato (*Solanum lycopersicum*) in an arid environment. Advanced Materials Research. 926-930: 4234-4237.

CHAPTER XIII

MOLECULAR BREEDING APPROACHES FOR INCREASED SALINITY TOLERANCE IN TOMATO (*Solanum Lycopersicum* L.)

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INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the major vegetables in the world. Although the origin of tomato is Latin America, it is distributed all over the world due to high adaptation capacity (Jenkins, 1948). Despite importance of the plant, biotic and abiotic stresses reduce tomato production. Abiotic stresses such as salinity, heat and drought lead major yield loses in tomato production. Therefore, abiotic stress management is a hot topic in tomato cultivation and breeding. Salinity stress as important as other stresses (heat and drought stresses) due to large (20% of total irrigated area) salt effected cultivation area (Ghassemi et al., 1995). The main reason for salination of soil is inappropriate irrigation and high irrigation demand in agricultural production, which will increase due to changing climate such as increased heat and decreased precipitation in near future. (Akça et al., 2020). Thus, development of cultivars tolerant to salinity stress is essential for sustainable agricultural production in salt affected areas. First step of such breeding purposes is to reveal mechanism of salinity stress tolerance in plants. Tomato is considered as semi tolerant plant for salinity stress (Maggio et al., 2004). However, higher salt concentration in the soil negatively affects tomato production.

Therefore, revealing the molecular mechanism of salt tolerance in tomato and identification of molecular mechanisms that increase salinity tolerance is essential. The present chapter reviews recent studies aimed to reveal molecular genetic mechanisms of salinity tolerance especially by using wild tomato species rather than general

aspect of salinity stress tolerance mechanisms reviewed in articles (Hurkman, 1992; Hussain et al., 2008; Parihar et al., 2015; İbrahimova et al., 2021).

1. MECHANISM OF SALINITY TOLERANCE IN PLANTS

Salinity is one of the major plant abiotic stresses that has negative effect on plant yield, and direct effect on plant growth and development. It leads water deficiency and nutritional imbalance due to uptake of Na^+ and Cl^- ions and finally causes oxidative stress due to the generation of reactive oxygen species (ROS) (Zhu, 2002; Hussain et al., 2008; Isayenkov, 2012; Isayenkov & Maathuis, 2019). Due to the importance of the salinity stress, many studies were performed to reveal molecular mechanisms in several plants (Sun et al., 2020; Liu et al., 2021). These studies showed that plants confer tolerance to salinity stress by activation of some cellular processes such as compartmentalization for decreasing Na^+ ion concentration in cell, transporting ions, production of osmoprotectants and polyamines and hormonal modulation. Molecular mechanisms of these salt stress response were also reviewed by Gupta & Huang (2004) and Tuteja (2007). Thus, present chapter intended to review recent studies and approaches to reveal molecular mechanism of salinityby using wild tomato species and to develop tomato cultivars have high salinity stress tolerance.

2. TOMATO AS A SEMI-SALINITY STRESS TOLERANT PLANT

Tomato is considered as moderately tolerant to salinity stress and can be cultivated in soil having a salt concentration of EC of 1.3~6 dS m^{-1} (Maggio et al., 2004). Despite the potential of the tomato in terms of salinity stress tolerance, this potential needs to be increased for sustainable tomato production in salt effected areas. There are two strategies to increase potential of tomato tolerance against salinity stress. The first one is unlocking the genetic potential of wild tomato species and the other is overexpression or silencing genes confer salinity tolerance in tomato.

2.1. Unlocking Genetic Potential of Wild Tomato Species for Salinity Tolerance

Cultivated tomato (*Solanum lycopersicum* L.) belongs *Solanum* genus which had three sections (*Lycopersicon, Juglandifolia* and *Lycopersicoides*). *Lycopersicon* section contains 12 wild tomato species (*Solanum arcanum, S. cheesmaniae, S. chilense, S. chmielewskii, S. corneliomulleri, S. galapagense, S. habrochaites, S. huaylasense, S. neorickii, S. pennellii, S. peruvianum* and *S. pimpinellifolium)* including *Solanum lycopersicum* cultivated tomato. (Knapp & Peralta, 2016). *Juglandifolia* section contains two species (*S. ochranthum* & *S. juglandifolium)* and *Lycopersicoides* section has two species, *S. lycopersicoides* and *S. sitiens* (Smith & Peralta, 2002; Knapp & Peralta, 2016). Figure 1 shows four of wild tomato species (*S. peruvianum, S. pimpinellifolium, S. lycopersicoides, S. habrochaites)*.

These wild tomato species have great potential for biotic and abiotic stress factors. For biotic stress factors, genes originating from wild tomato species were identified in the tomato genome and introgressed into cultivated tomato (Van Ooijen et al., 2007). In addition, the importance of wild tomato species for biotic stress, studies showed that these wild tomato species had promising genetic potential for abiotic stresses. Transferring this genetic potential to cultivated tomato for the development of tomato cultivars confer tolerance to abiotic stress requires four steps;

1. Evaluation of wild tomato species and accessions for abiotic stress for determination of gene resources tolerant to abiotic stress,
2. Identification of genes or loci control stress tolerance,
3. Development of molecular tools for marker assisted selection (MAS),
4. Introgression of these identified loci to cultivated tomato.

This breeding strategy has been commonly used in plant genomics and had promising results for abiotic stress resistance controlled by single gene (reviewed by Foolad & Panthee (2012)). Application of this strategy in abiotic stress tolerance is challenging due to quantitative nature and complex molecular mechanism of abiotic stress.

2.1.1. Evaluation of Wild Tomato Species for Salinity Tolerance

The first step of breeding for salinity tolerance is the determination of genetic resources have high potential for salinity stress. Screening of

genetic resources in tomato for salinity tolerance was firstly performed by Lyon (1941). The study reported that *S. pimpinellifolium* have high potential for salinity tolerance. After that, many studies aimed to screen tomato genetic resources for salinity tolerance were performed. Early studies showed that other wild tomato species, *S. pennellii*, *S. cheesmaniae* and *S arcanum* (Tal, 1971; Dehan & Tal, 1978; Rush & Epstein, 1976; Foolad & Lin, 1997) have also potential to provide tolerance against salt stress. In addition to earlier studies, recent studies still focused on screening of wild tomato species for salinity tolerance. Sixty-seven Galapagos tomato accessions (39 are *S. cheesmaniae* and 28 are *S. galapagense*) and three accesions (LA0317, LA1449, and LA1403) were screened and found to have high salinity tolerance (Pailles et al., 2020). In another study, rooting of cultivated tomato and *S. pennellii* exposed to 0, 35, 70, 105, 140, 175 and 210 mM NaCl stress were evaluated, and the study reported that although the roots of *S. pennellii* developed, cultivated tomato did not show developed roots under stress conditions. Thus, the study showed high genetic potential of *S. pennellii* for salinity tolerance and suggested that root formation can be a screening parameter for salinity tolerance (Cano et al., 1998).

Although earliest studies focused on wild tomato species for salt tolerance, cultivated tomato accessions and cultivars were also screened to determine salt tolerant tomato genetic resources. In a study performed by Chookhampaeng et al. (2007), hydroponically grown seedlings of 13 tomato cultivars from Thailand exposed to 200 mM NaCl were investigated for salinity tolerance and reported reasonable

variation of tomato cultivars for salinity tolerance. In another study, the salinity tolerance of 18 tomato cultivars grown in a nutrient solution with 12 dS m^{-1} NaCl were tested and reported that although all growth parameters were reduced, the effect of salinity stress on salt sensitive cultivars was more dramatic than on salt tolerant cultivars. One tomato cultivar found to be the most tolerant (H-2710) in this study (Turhan et al., 2009). Similar results were reported in study, in which 72 tomato cultivars grown in Hoagland solution had salinity levels of 10 and 15 dS m^{-1}. Although all the parameters of all cultivars were decreased, a total of six cultivars were found to be salinity tolerant (Saeed et al., 2010). There are many studies performed to characterize small subset of tomato populations for salt stress tolerance. All studies have shown that although all tomato cultivars are affected from salinity stress, there are differences in salt influence across populations. Salinity stress had minimum effect on salt stress tolerant cultivars (Singh et al., 2012; Siddiky et al., 2012; Seth & Kendurkar, 2015; Navin-Pradhan et al., 2015; Rashed et al., 2016; Kumar et al., 2017; Raza et al., 2017; Haq et al., 2017; Dasgan et al., 2018; Devi & Arumugam, 2019).

In addition to phenotypic evaluation of salt stress such as Na^{+}, K^{+} Ca^{+2} concentrations of shoots, dried biomass, shoot and root lengths, fresh shoot and root weights number of flowers, number of flowers shed, number of fruits, number of leaves/plant and number of days for fruit setting were commonly used in the studies mentioned above, some biochemical and molecular markers are also used for salinity tolerance screening of tomato cultivars. Proline content, lipid peroxidation and

H_2O_2 content are the main biochemical markers for assessing the salinity tolerance level of tomato cultivars (Juan et al., 2005; Kong-ngern et al., 2012). Furthermore, the expressions of genes have function in salinity tolerance, discussed in section 4, can be used as molecular markers of decent salinity tolerant tomato cultivars (Gharsallah et al., 2016).

Screening of wild tomato species and cultivars based on morphological, biochemical and molecular parameters demonstrated that tomato genetic recourses such as wild tomato species or local varieties have reasonable genetic potential for salinity tolerance. Molecular mechanism of this high potential needed to be further elucidated.

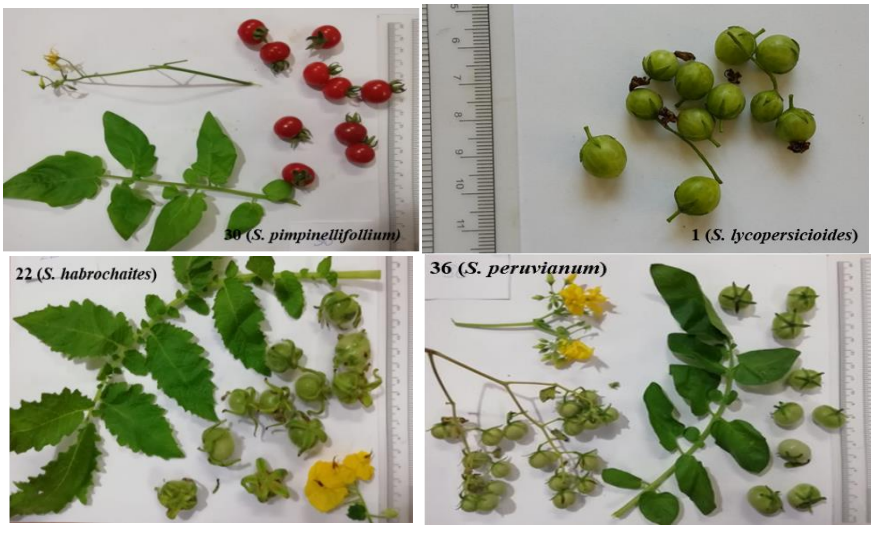

Figure 1: Wild Tomato Species **(***S. peruvianum, S. pimpinellifolium, S. lycopersicoides, S. habrochaites*) (Original by Kabaş)

2.1.2. Identification of Genes or Loci Control Stress Tolerance

The next step after identification of salt tolerant tomato genetic resources is to reveal molecular mechanism of the salt tolerance using omics approaches (genomics, transcriptomics, proteomics, and metabolomics). Uncovering the molecular mechanism of salinity tolerance includes identification or mapping loci that control the trait, annotations of loci for identification of genes and alleles to increase tolerance, and development of molecular genetic tools for marker assisted selections. Therefore, genomic and transcriptomic approaches have been used for reveling mechanism of the stress tolerance (Chaudhary et al., 2019; Sun et al., 2020).

2.1.2.1. Genomic Studies for Mapping Qtls Control Salinity Tolerance

QTL (Quantitative Trait Locus) mapping is the unique genomic approach to map the QTLs in tomato genome due to quantitative nature of the tolerance in tomato. For this reason, many mapping studies have been performed in tomato (Diouf et al., 2018; Wen et al., 2019). QTL mapping studies were mainly performed on salinity tolerant *S. pimpinellifolium* and *S. pennellii*. The first QTL mapping study was performed in an F2 population derived from a cross between *S. lycopersicum* and *S. pennellii* using 16 isozyme loci. A total of three loci (*Prx-7* on chromosome 3, and *6Pgdh-2* and *Pgi-1* on chromosome 12) were mapped to have a positive effect on salinity tolerance and a negative effect of *Got-2* on chromosome 7 and *Aps-2* on chromosome 8 in the tomato genome. (Foolad & Jones, 1993). Another study

performed QTL mapping in F2 population derived from a cross between *S. lycopersicum* and *S. pennellii* using isozyme and RFLP (Restriction Fragment Length Polymorphism). As a result, eight QTLs were identified on seven chromosomes 1, 2, 3, 7, 8, 9 and 12. QTLs on chromosomes 1, 3, 9 and 12 had favorable alleles for salinity tolerance (Foolad et al., 1997). A similar study was performed using 53 RAPD (Random Amplified Polymorphic DNA) markers and a total of 13 markers found to be associated to salinity tolerance, in which five of the QTLs were originated from *S. pennellii* (LA716) (Foolad & Chen, 1998). Finally, an introgression library containing 52 *S. pennellii* lines for salinity stress were evaluated to identify antioxidant response QTLs (Frary et al., 2010). Although *S. lycopersicum* increased antioxidant production in the control condition, *S. pennellii* showed greater antioxidant production. A total of 125 antioxidant response QTLs were detected under salinity stress and control conditions (Frary et al., 2010). Subsequently, a line of the library IL8-3 was determined that the stress tolerance mechanism of the QTL further tested for salinity stress tolerance and is involved in osmotic regulation and abscisic acid (ABA) response (Uozumi et al., 2012).

QTLs, originating from *S. pimpinellifolium* control salinity tolerance were also mapped. Initially two QTL mapping studies were performed by Foolad et al. (1998) and Foolad et. al. (1999). Similar populations (BC1) derived from the cross between *S. lycopersicum* and *S. pimpinellifolium* were genotyped using RFLP markers. A total of seven QTLs were detected for salinity tolerance.

Also in a study, multi-parent advanced generation intercross (MAGIC) tomato population derived from four accessions of small fruit group *S. lycopersicum* var. cerasiforme and large fruit group *S. lycopersicum* var. lycopersicum were used identify QTLs drought and salinity stress tolerance and a total of 54 QTLs were detected (Diouf et al., 2018).

In addition to *S. pennellii* and *S. pimpinellifolium*, specific QTLs from *S. lycopersicoides*, another wild tomato species, controlling salinity tolerance identified using 56 ILs library. Six major QTLs were identified. In the same study, the same IL library of *S. pennellii* was also used for QTL mapping for salinity tolerance, and four QTLs were detected on three chromosomes (6, 7 and 11) (Li et al., 2011). The QTL on chromosome 6 were co-localized in two IL libraries, highlighting the importance of this locus for salinity tolerance in tomato.

As discussed above, several QTL mapping studies have been conducted for unlocking genetic potential of two main wild tomato species (*S. pennellii* and *S. pimpinellifolium*) and *S. lycopersicoides*. These studies demonstrated that salinity tolerance is a quantitative trait and controlled by many loci in the genome. Although quantitative traits are influenced from genetic background and environment, a meta-QTL analysis covering all salinity stress related QTLs should be performed for a more complete picture of QTLs control tolerance. Furthermore, QTL mapping studies have bee limited to three two species and other tomato species and tomato landraces should be used as parents of segregating populations or association panels for detecting QTLs and favorable

alleles for salinity tolerance. For higher resolution in detecting QTLs in tomato, other genomics approaches such as association mapping or genomic selection methods should be applied in tomato for salinity tolerance.

2.1.2.2. Transcriptomic Studies for Identification Genes Involved in Salinity Stress Tolerance

Transcriptomic methods were used to detect DEGs (Differentially Expressed Genes) under control and stress conditions. The first transcriptomic method was used to detect genes involved in salinity tolerance in tomato by Ouyang et al. (2007). In the study, two transcriptomic methods (subtractive hybridization and microarray) were applied in a salt tolerant (LA2711) and salt-sensitive cultivars (ZS-5). A total of 201 genes found to be differentially expressed in LA2711 or ZS-5 upon 30 min of salt stress treatment. In another study, DEGs of salt tolerant *S. pimpinellifolium* (PI365967) and salt-sensitive *S. lycopersicum* cv. Moneymaker were determined after treatment of 200 mM NaCl by using The Affymetrix Tomato Genome Array containing 9.200 probes. As a result, salt hypersensitive (SOS) pathway of PI365967 was more active than Moneymaker. Also, the concentration of Na^+ ions was lower in PI365967. Salicylic acid-binding protein 2 (SABP2) and two genes encoding lactoylglutathione lyase and few glutathione S-transferase were found to be induced in PI365967. The study indicated that possible role of these genes in salinity stress (Sun et al., 2010). The most comprehensive transcriptomic study was performed by Kashyap et al. (2020). In the

study, transcriptome changes of 1-month-old seedlings of salt tolerant *S. chilense* and salt sensitive *S. lycopersicum* were investigated by RNA sequencing (RNA-Seq) using Illumina HiSeq 2000 NGS platform. De novo transcriptome assembly generated 514.747 unigenes. A total of 134.566 and 130.592 genes found to be up and down-regulated, respectively. Up regulated genes mainly had function in cytokinin, ethylene, auxin, abscisic acid, gibberellin, and Ca^{+2} mediated signaling pathways. The study pointed out that Wnt signaling pathway has an important role in salinity stress tolerance. Moreover, several genes of proline and arginine metabolism, ROS scavenging system, transporters, osmotic regulation, defense and stress response, homeostasis and transcription factors found to be stress induced.

3. TRANSGENIC APPROACHES FOR INCREASED SALINITY TOLERANCE

Conventional and molecular breeding efforts for salinity tolerance is difficult due to quantitative nature of the trait. Thus, transgenic approach leads overexpression or silencing of genes related to salinity stress tolerance is a promising method of targeted breeding for increased salinity tolerance in plants. Molecular genetic studies in plants and even in yeast identified salinity tolerance genes confer tolerance to salinity stress. In tomato, many transgenic studies have been conducted to overexpress genes for increased salinity tolerance and to validate the function of candidate genes in stress conditions. Overexpression of *HAL1* gene identified in yeast was performed in two studies using *Agrobacterium tumefaciens*-mediated transformation and

HAL1 overexpression increased salt tolerance. *HAL1* increased water and K contents in yeast indicating similar mechanism of plant and yeast for salinity tolerance. (Gisbert et. al., 2000; Rus et al., 2001). In another study, two genes (*SlAREB1* and *SlAREB2)* belong to protein family of abscisic acid-responsive element binding protein (AREB)/abscisic acid-responsive element binding factor (ABF) subfamily of basic leucine zipper (bZIP) transcription factors overexpressed in tomato. The study showed that two genes increased salinity tolerance, but *SlAREB1* had greater salinity tolerance function than *SlAREB2*. Furthermore, microarray and cDNA-amplified fragment length polymorphism (AFLP) analyses of transgenic tomato cultivars showed upregulated genes encoding oxidative stress-related proteins, lipid transfer proteins (LTPs), transcription regulators and late embryogenesis abundant proteins (Orellana et al., 2010). Another study also showed that overexpression of *SlAREB* increased salinity tolerance (Hsieh et al., 2010). Overexpression of two genes have function in glyoxalase system, increased salinity tolerance in tomato and reduced oxidative stress at 800 mM salt stress (Viveros et al., 2013). In another study, downregulation of *SlHB2* gene encoding HD-Zip I transcription factors by using RNA interference method increased salinity and drought stress tolerance in tomato. The study also pointed out up regulation of stress related genes and negative effect of *SlHB2* gene for salinity and drought stress tolerance (Hu et al., 2017). In another study, a WRKY transcription factor (*SlWRKY3*) resulted in increased salinity tolerance, induction of stress related genes, and reduced oxidative stress (Hichri et al., 2017). In another study, transformation of choline oxidase

gene from *Arthrobacter globiformis* increased salinity tolerance by decreasing the Na^+/K^+ ratios in the cells in tomato (Wei et al., 2017). Similar to these studies, overexpression of several genes such as R2R3-type MYB transcription factor called *SlMYB1*, ZAT protein family of plant transcription factors (TFs), *BcZAT12* gene, BZR/BES transcription factor *SlBZR1*, *SlCOMT1* Melatonin Synthesis-Related Gene, *SlDREB2*, a tomato dehydration-responsive element-binding 2, leaded increased salinity stress tolerance in tomato (Hichri et al., 2016; Liu et al., 2019; Zhang et al., 2020; Rai et al., 2021; Jia et al., 2021). In a recent study, CRISPR/Cas9 genome editing technology was used to develop tomato cultivars increased salinity tolerance. In the study, excision of protein domains of tomato hybrid proline-rich protein 1 (HyPRP1), a negative regulator of salt stress responses, increased salinity tolerance (Tran et al., 2021).

CONCLUSION

Salinity stress management is important subject in agriculture due to inappropriate irrigation. Although tomato is semi- tolerant for salinity stress, higher salt concentration in the soil negatively affect tomato production. Thus, development of tomato cultivars confer resistance to salinity stress is essential for sustainable tomato production in salt effected cultivation area. Therefore, many studies were performed for evaluation of salinity tolerance potential of wild tomato species and accessions. The studies reported that wild tomato species such as *S. pennellii* and *S. pimpinellifolium* are tolerant to salinity stress. Although many QTL mapping studies were performed, identified QTLs were not

useful for tomato breeding. Although Transgenic approach involves overexpression or silencing of salinity tolerance genes have more promising results than molecular breeding methods such as MAS, cutting-edge genomics approaches such as genomic selection and candidate gene association mapping should be used to develop molecular tools for salinity tolerance breeding as non-GMO tools.

REFERENCES

Akça, E., Aydın, M., Kapur, S., Kume, T., Nagano, T., Watanabe, T., Çilek, A., & Zorlu, K. (2020). Long-term monitoring of soil salinity in a semi-arid environment of Turkey. Catena, 193: 104614.

Cano, E.A., Pérez-Alfocea, F., Moreno, V., Caro, M., & Bolarín, M.C. (1998). Evaluation of salt tolerance in cultivated and wild tomato species through in vitro shoot apex culture. Plant Cell, Tissue and Organ Culture, 53(1): 19-26.

Chaudhary, J., Khatri, P., Singla, P., Kumawat, S., Kumari, A., Vikram, A., & Deshmukh, R. (2019). Advances in omics approaches for abiotic stress tolerance in tomato. Biology, 8(4): 90.

Chookhampaeng, S., Pattanagul, W., & Theerakulpisut, P. (2007). Screening some tomato commercial cultivars from Thailand for salinity tolerance. Asian Journal of Plant Sciences, 6(5): 788-794.

Dasgan, H.Y., Bayram, M., Kusvuran, S., Coban, G.A., & Akhoundnejad, Y. (2018). Screening of tomatoes for their resistance to salinity and drought stress. Screening, 8(24): 31-37.

Dehan, K. & Tal, M. (1978). Salt tolerance in the wild relatives of the cultivated tomato: responses of *Solanum pennellii* to high salinity. Irrigation Science, 1(1): 71-76.

Devi, N.D. & Arumugam, T. (2019). Screening of tomato genotypes at various levels of salinity. Journal of Pharmacognosy and Phytochemistry, 8(3): 3199-3201.

Diouf, I.A., Derivot, L., Bitton, F., Pascual, L., & Causse, M. (2018). Water deficit and salinity stress reveal many specific QTL for plant growth and fruit quality traits in tomato. Frontiers in Plant Science, 9: 279.

Foolad, M.R. & Chen, F.Q. (1998). RAPD markers associated with salt tolerance in an interspecific cross of tomato (*Lycopersicon esculentum*× *L. pennellii*). Plant Cell Reports, 17(4): 306-312.

Foolad, M.R. & Jones, R.A. (1993). Mapping salt-tolerance genes in tomato (*Lycopersicon esculentum*) using trait-based marker analysis. Theoretical and Applied Genetics, 87(1): 184-192.

Foolad, M.R. & Lin, G.Y. (1997). Genetic potential for salt tolerance during germination in *Lycopersicon* species. HortScience, 32(2): 296-300.

Foolad, M.R. & Panthee, D.R. (2012). Marker-assisted selection in tomato breeding. Critical Reviews in Plant Sciences, 31(2): 93-123.

Foolad, M.R., Chen, F.Q., & Lin, G.Y. (1998). RFLP mapping of QTLs conferring salt tolerance during germination in an interspecific cross of tomato. Theoretical and Applied Genetics, 97(7): 1133-1144.

Foolad, M.R., Lin, G.Y., & Chen, F.Q. (1999). Comparison of QTLs for seed germination under non-stress, cold stress and salt stress in tomato. Plant Breeding, 118(2): 167-173.

Frary, A., Göl, D., Keleş, D., Ökmen, B., Pınar, H., Şığva, H.Ö., & Doğanlar, S. (2010). Salt tolerance in *Solanum pennellii*: antioxidant response and related QTL. BMC Plant Biology, 10(1): 1-16.

Gharsallah, C., Fakhfakh, H., Grubb, D., & Gorsane, F. (2016). Effect of salt stress on ion concentration, proline content, antioxidant enzyme activities and gene expression in tomato cultivars. AoB Plants, 8: 1-21.

Ghassemi, F., Jakeman, A.J., & Nix, H.A. (1995). Salinisation of land and water resources: human causes, extent, management and case studies. CAB international.

Gisbert, C., Rus, A.M., Bolarín, M.C., López-Coronado, J.M., Arrillaga, I., Montesinos, C., & Moreno, V. (2000). The yeast HAL1 gene improves salt tolerance of transgenic tomato. Plant Physiology, 123(1): 393-402.

Gupta, B. & Huang, B. (2014). Mechanism of salinity tolerance in plants: physiological, biochemical, and molecular characterization. International Journal of Genomics, 2014.

Haq, M. E., Zeba, N., Akter, R., Begum, B., & Harun-Ur-Rashid, M. (2017). Screening and identification of salt tolerant genotypes based on agromorphogenic traits of tomato (*Solanum lycopersicum* L.). Annual Research & Review in Biology, 1-11.

Hichri, I., Muhovski, Y., Clippe, A., Žižková, E., Dobrev, P.I., Motyka, V., & Lutts, S. (2016). SlDREB2, a tomato dehydration-responsive element-binding 2 transcription factor, mediates salt stress tolerance in tomato and *Arabidopsis.* Plant, Cell & Environment, 39(1): 62-79.

Hichri, I., Muhovski, Y., Žižková, E., Dobrev, P.I., Gharbi, E., Franco-Zorrilla, J.M., & Lutts, S. (2017). The *Solanum lycopersicum* WRKY3 transcription factor SlWRKY3 is involved in salt stress tolerance in tomato. Frontiers in Plant Science, 8: 1343.

Hsieh, T.H., Li, C.W., Su, R.C., Cheng, C.P., Tsai, Y.C., & Chan, M.T. (2010). A tomato bZIP transcription factor, SlAREB, is involved in water deficit and salt stress response. Planta, 231(6): 1459-1473.

Hu, J., Chen, G., Yin, W., Cui, B., Yu, X., Lu, Y., & Hu, Z. (2017). Silencing of SlHB2 improves drought, salt stress tolerance, and induces stress-related gene expression in tomato. Journal of Plant Growth Regulation, 36(3): 578-589.

Hurkman, W.J. (1992). Effect of salt stress on plant gene expression: a review. Plant and Soil, 146(1): 145-151.

Hussain, T.M., Ch, T., Hazara, M., Sultan, Z., Saleh, B.K., & Gopal, G.R. (2008). Recent advances in salt stress biology a review. Biotechnology and Molecular Biology Reviews, 3(1): 8-13.

İbrahimova, U., Kumari, P., Yadav, S., Rastogi, A., Antala, M., Suleymanova, Z., & Brestic, M. (2021). Progress in understanding salt stress response in plants using biotechnological tools. Journal of Biotechnology, 329: 180-191.

Isayenkov, S.V. & Maathuis, F.J. (2019). Plant salinity stress: many unanswered questions remain. Frontiers in Plant Science, 10: 80.

Isayenkov, S.V. (2012). Physiological and molecular aspects of salt stress in plants. Cytology and Genetics, 46(5): 302-318.

Jenkins, J.A. (1948). The origin of the cultivated tomato. Economic Botany, 2(4): 379-392.

Jia, C., Zhao, S., Bao, T., Zhao, P., Peng, K., Guo, Q., & Qin, J. (2021). Tomato BZR/BES transcription factor SlBZR1 positively regulates BR signaling and salt stress tolerance in tomato and *Arabidopsis*. Plant Science, 302: 110719.

Juan, M., Rivero, R. M., Romero, L., & Ruiz, J.M. (2005). Evaluation of some nutritional and biochemical indicators in selecting salt-resistant tomato cultivars. Environmental and Experimental Botany, 54(3): 193-201.

Kashyap, S.P., Prasanna, H.C., Kumari, N., Mishra, P., & Singh, B. (2020). Understanding salt tolerance mechanism using transcriptome profiling and de novo assembly of wild tomato *Solanum chilense*. Scientific Reports, 10(1): 1-20.

Knapp, S. & Peralta, I.E. (2016). The tomato (*Solanum lycopersicum* L., Solanaceae) and its botanical relatives. In: The Tomato Genome. Springer, Berlin, Heidelberg, pp. 7-21.

Kong-ngern, K., Bunnag, S., & Theerakulpisut, P. (2012). Proline, hydrogen peroxide, membrane stability and antioxidant enzyme activity as potential indicators for salt tolerance in rice (*Oryza sativa* L.). International Journal of Botany, 8(2): 54-65.

Kumar, P.A., Reddy, N.N., & Lakshmi, N.J. (2017). Screening tomato genotypes for salt tolerance. Int. J. Curr. Microbiol. App. Sci, 6(11): 1037-1049.

Li, J., Liu, L., Bai, Y., Zhang, P., Finkers, R., Du, Y., & Van Heusden, A.W. (2011). Seedling salt tolerance in tomato. Euphytica, 178(3): 403-414.

Liu, D., Dong, S., Bo, K., Miao, H., Li, C., Zhang, Y., & Gu, X. (2021). Identification of QTLs controlling salt tolerance in cucumber (*Cucumis sativus* L.) Seedlings. Plants, 10(1): 85.

Liu, D.D., Sun, X.S., Liu, L., Shi, H.D., Chen, S.Y., & Zhao, D.K. (2019). Overexpression of the melatonin synthesis-related gene SlCOMT1 improves the resistance of tomato to salt stress. Molecules, 24(8): 1514.

Lyon, C.B. (1941). Responses of two species of tomatoes and the F1 generation to sodium sulphate in the nutrient medium. Botanical Gazette, 103(1): 107-122.

Maggio, A., De Pascale, S., Angelino, G., Ruggiero, C., & Barbieri, G. (2004). Physiological response of tomato to saline irrigation in long-term salinized soils. European Journal of Agronomy, 21(2): 149-159.

Navin-Pradhan, P.P., Manimurugan, C., Tiwari, S.K., Sharma, R.P., & Singh, P.M. (2015). Screening of tomato genotypes using osmopriming with PEG 6000 under salinity stress. Res. Environ. Life Sci., 8(2): 245-250.

Orellana, S., Yanez, M., Espinoza, A., Verdugo, I., Gonzalez, E., RUIZLARA, S.I.M.Ó.N., & Casaretto, J.A. (2010). The transcription factor SlAREB1 confers drought, salt stress tolerance and regulates biotic and abiotic stress-related genes in tomato. Plant, Cell & Environment, 33(12): 2191-2208.

Ouyang, B., Yang, T., Li, H., Zhang, L., Zhang, Y., Zhang, J., ... & Ye, Z. (2007). Identification of early salt stress response genes in tomato root by suppression subtractive hybridization and microarray analysis. Journal of Experimental Botany, 58(3): 507-520.

Pailles, Y., Awlia, M., Julkowska, M., Passone, L., Zemmouri, K., Negrão, S., & Tester, M. (2020). Diverse traits contribute to salinity tolerance of wild tomato seedlings from the Galapagos Islands. Plant physiology, 182(1): 534-546.

Parihar, P., Singh, S., Singh, R., Singh, V.P., & Prasad, S.M. (2015). Effect of salinity stress on plants and its tolerance strategies: a review. Environmental science and Pollution Research, 22(6): 4056-4075.

Rai, A.C., Rai, A., Shah, K., & Singh, M. (2021). Engineered BcZAT12 gene mitigates salt stress in tomato seedlings. Physiology and Molecular Biology of Plants, 27(3): 535-541.

Rashed, M.R.U., Roy, M.R., Paul, S.K., & Haque, M.M. (2016). In vitro screening of salt tolerent genotypes in tomato (*Solanum lycopersicum* L.). Journal of Horticulture, 3(4):1-8.

Raza, M.A., Saeed, A., Munir, H., Ziaf, K., Shakeel, A., Saeed, N., & Rehman, F. (2017). Screening of tomato genotypes for salinity tolerance based on early growth attributes and leaf inorganic osmolytes. Archives of Agronomy and Soil Science, 63(4): 501-512.

Rus, A.M., Estan, M.T., Gisbert, C., Garcia-Sogo, B., Serrano, R., Caro, M., ... & Bolarin, M.C. (2001). Expressing the yeast *HAL1* gene in tomato increases fruit yield and enhances K^+/Na^+ selectivity under salt stress. Plant, Cell & Environment, 24(8): 875-880.

Rush, D.W. & Epstein, E. (1976). Genotypic responses to salinity: Differences between salt-sensitive and salt-tolerant genotypes of the tomato. Plant Physiology, 57(2): 162-166.

Saeed, A., Khan, A.A., Saeed, N., & Saleem, M.F. (2010). Screening and evaluation of tomato germplasm for NaCl tolerance. Acta Agriculturae Scandinavica Section B–Soil and Plant Science, 60(1): 69-77.

Seth, R. & Kendurkar, S. (2015). In vitro screening: an effective method for evaluation of commercial cultivars of tomato towards salinity stress. International Journal of Current Microbiology and Applied Sciences, 4(1): 725-730.

Siddiky, M.A., Sardar, P.K., Hossain, M.M., Khan, M.S., & Uddin, M.K. (2012). Screening of different tomato varieties in saline areas of Bangladesh. International Journal of Agricultural Research, Innovation and Technology (IJARIT), 2: 13-18.

Singh, J., Sastry, E.D., & Singh, V. (2012). Effect of salinity on tomato (*Lycopersicon esculentum* Mill.) during seed germination stage. Physiology and Molecular Biology of Plants, 18(1): 45-50.

Smith, S.D. & Peralta, I.E. (2002). Ecogeographic surveys as tools for analyzing potential reproductive isolating mechanisms: an example using *Solanum juglandifolium* Dunal, *S. ochranthum* Dunal, *S. lycopersicoides* Dunal, and *S. sitiens* IM Johnston. Taxon, 51(2): 341-349.

Sun, H., Sun, X., Wang, H., & Ma, X. (2020). Advances in salt tolerance molecular mechanism in tobacco plants. Hereditas, 157(1): 1-6.

Sun, W., Xu, X., Zhu, H., Liu, A., Liu, L., Li, J., & Hua, X. (2010). Comparative transcriptomic profiling of a salt-tolerant wild tomato species and a salt-sensitive tomato cultivar. Plant and Cell Physiology, 51(6): 997-1006.

Tal, M. (1971). Salt tolerance in the wild relatives of the cultivated tomato: Responses of *Lycopersicon esculentum*, *L. peruvianum*, and *L. esculentum* minor to sodium chloride solution. Australian Journal of Agricultural Research, 22(4): 631-638.

Tran, M.T., Doan, D.T.H., Kim, J., Song, Y.J., Sung, Y.W., Das, S., & Kim, J.Y. (2021). CRISPR/Cas9-based precise excision of SlHyPRP1 domain (s) to obtain salt stress-tolerant tomato. Plant Cell Reports, 40(6): 999-1011.

Turhan, A., Seniz, V., & Kusçu, H. (2009). Genotypic variation in the response of tomato to salinity. African Journal of Biotechnology, 8(6): 1062-1068.

Tuteja, N. (2007). Mechanisms of high salinity tolerance in plants. Methods in Enzymology, 428: 419-438.

Uozumi, A., Ikeda, H., Hiraga, M., Kanno, H., Nanzyo, M., Nishiyama, M., ... & Kanayama, Y. (2012). Tolerance to salt stress and blossom-end rot in an introgression line, IL8-3, of tomato. Scientia Horticulturae, 138: 1-6.

Van Ooijen, G., Van den Burg, H.A., Cornelissen, B.J., & Takken, F.L. (2007). Structure and function of resistance proteins in solanaceous plants. Annu. Rev. Phytopathol., 45: 43-72.

Viveros, M.F.Á., Inostroza-Blancheteau, C., Timmermann, T., González, M., & Arce-Johnson, P. (2013). Overexpression of GlyI and GlyII genes in transgenic tomato (*Solanum lycopersicum* Mill.) plants confers salt tolerance by decreasing oxidative stress. Molecular Biology Reports, 40(4): 3281-3290.

Wei, D., Zhang, W., Wang, C., Meng, Q., Li, G., Chen, T.H., & Yang, X. (2017). Genetic engineering of the biosynthesis of glycinebetaine leads to alleviate salt-induced potassium efflux and enhances salt tolerance in tomato plants. Plant Science, 257: 74-83.

Wen, J., Jiang, F., Weng, Y., Sun, M., Shi, X., Zhou, Y., ... & Wu, Z. (2019). Identification of heat-tolerance QTLs and high-temperature stress-responsive genes through conventional QTL mapping, QTL-seq and RNA-seq in tomato. BMC Plant Biology, 19(1): 1-17.

Zhang, X., Chen, L., Shi, Q., & Ren, Z. (2020). SlMYB102, an R2R3-type MYB gene, confers salt tolerance in transgenic tomato. Plant Science, 291: 110356.

Zhu, J.K. (2002). Salt and drought stress signal transduction in plants. Annual Review of Plant Biology, 53(1): 247-273.

CHAPTER XIV

BROOMRAPE (*Phelipanche aegyptica* / *Phelipanche ramosa*) MANAGEMENT IN TOMATO GROWING

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INTRODUCTION

Tomato, one of the most consumable agricultural products in the World is the edible berry of the *Solanum lycopersicum* evolved from wild ancestor of *S. pimpinellifolium* plants (van der Knaap et al., 2014). It is originated from Peru-Ecuador area (Jenkins, 1948). Even if it was discovered in the 16th century by Europeans, nowadays it is grown a wide area around the World. According to estimates it was firstly domesticated to use as food by Mexican indigenous Spanish colonialists encountered tomato when they conquest the Aztec empire (Bergougnoux, 2014).

The global tomato production is 180.8 million tonnes. It is almost produced by all countries in the world. When all countries are examined, it is clearly that China is the most prominent country with 35% share in the world it is followed by respectively India and Turkey. Table 1 shows production value and area for top 10 tomato producer countries (FAO, 2019). According to different source tomato has 190.4 billion $ market size.

Tomato, which is the second most important vegetable in the world after potatoes, can be utilised many different areas such as fresh, cooked, sauce and drink sector. It supports human health positively with the vitamins and minerals it contains. It contains flavonoids such as vitamin C and E, lycopene, β-carotene, lutein and quercetin, which have antioxidant properties (Dorais et al., 2008).

Table 1: Tomato Cultivation Area and Production by Country (FAO, 2019)

Country	Production Area (Ha)	Production (tonnes)
China	1.086.771	62.869.502
India	781.000	19.007.000
Turkey	181.488	12.841.990
USA	110.760	10.858.990
Egypt	173.276	6.751.856
Italy	91.410	5.252.690
Iran	121.203	5.248.904
Spain	56.940	5.000.560
Mexico	87.917	4.271.914
Brazil	54.537	3.917.967

Numerous commercial and local varieties have been widely grown for a long time in different regions and season through greenhouses and other cultivation methods around the world. While it depends on growing type and variety of tomato, its height is generally growth 1-3 meters.

Table 2: Common Tomato Types

Number	The common types of tomatoes
1	Beefsteak
2	Plum
3	Yellow
4	Cherry
5	Campari
6	Pear
7	Brandywine
8	Cherokee Purple

Mainly, there are two type of tomato determinate and indeterminate. While indeterminate tomato varieties are growing perennial in their originate habitat, determinate varieties are grown annually.

Furthermore, the size of tomato fruit is very changeable independently of growing type. Table 2 demonstrates the common tomato types.

Even if tomato growing is becoming popular from day to day, there are many problems in the growing. Because numerous factors are narrowing down the tomato growing. Limitations can be divided two main group as abiotic stress factors and biotic stress factors. Moreover, these factors cause billions dollar loses in tomato growing so farmers have to make provision for these factors. Nowadays, due to climate change abiotic stress factors are gaining importance day by day. Even if there are many abiotic stress factors such as winds, flood and natural disaster in tomato, mainly there are 4 factors. These are; salinity, heat, drought, cold stress. However, biotic stress factors cannot be ignored these limitation factors they are as important as abiotic stress factors. Today, there are more than 200 biotic stress factors that seriously effects on tomato growing. Although there are many biotic stress factors, it can be mentioned mainly 5 groups. These 5 groups consist of fungal diseases, viral diseases, bacterial diseases, insects and weeds. Especially weeds are one of the most important biotic stress factors in tomato because struggling with weed is both expensive and hard. Although, there are some studies with regard to breeding of resistance tomato varieties, the number of studies is not sufficiently.

Weeds lead to a decrease in the yield and quality of crops by competing for nutrients, water, space and light (Zimdahl, 2018). Additionally, weeds can be harmful to harbour nematodes (Rich et al., 2009), insects (Capinera, 2005) and diseases (Duffus, 1971) that add increased cost of

protection. Therefore, in tomato cultivation weed control is the one of the most important part as it is mentioned before. It is obviously that, weeds give rise to decreasing of efficiency inputs such as water and fertilizer. For this reason, it can be said that, weeds cause wide range of damage in terms of both biotic and abiotic stress factors. Parasitic plants in particular cause significant yield losses of tomatoes and it very sensitive to the broomrape species.

1. GENERAL DAMAGE, DISTRIBUTION OF BROOMRAPES

Broomrapes of several of the genus *Orobanche, Phelipanche* and *Striga* species from the Orobancheae family cause damage in agricultural areas. Orobanche and Phelipanche species damage dicotyledonous plants, while the genus Striga harms monocotyledonous plants. Parasitic plants are evolutionarily divided into two groups as holoparasites and hemiparasites due to their chlorophyll content. While hemiparasites can photosynthesize, holoparasites cannot photosynthesize because they have no leaves.

Broomrape are commonly seen in countries with Mediterranean coastlines in the world. Although *P. ramosa* can be seen from the Mediterranean to Central Europe, it has also spread to the Middle East and North Africa. It is also found in many parts of East Africa (Babiker et al., 2007), South Africa, Cuba and Central America (Parker, 2013). Although the host range of *P. ramosa* is very broad, they cause considerable yield losses, especially in tomatoes and tobacco from the Solanaceae family.

Phelipanche aegyptica and *Phelipanche ramosa* are obligate root parasitic weeds that attack economically important crops in numerous plant families including Solanaceae. Within this family the tomato is the most susceptible.

There are studies on product loss from *P. ramosa* in different parts of the world. It has been reported that the yield loss of tomato yield due to P. ramosa is 21-29% in the USA (Cordas, 1973) and 24% in Turkey (Aksoy & Uygur, 2008).

After the seeds of the broomrape fall into the ground, it recognizes the phytohormones secreted by the root of the host plant and begins to germinate, forming a structure called haustorium by working with the germ tube that expands it at the root of the host plant sticks. By providing nutrients and water from the host plant, it causes economic loss by weakening the host plant. In cases where germination does not occur, the seeds can remain dormant in the soil for about 10 years.

2.CONTROL METHODS OF BROOMRAPE

2.1. Mechanical and Cultural Methods

2.1.1. Preventive Measures

The hardest part of weed management is prevention, defined as preventing weeds from contaminating an area. It is a practical control method to manage weeds but it takes patience and time to be successful with this method. Prevention is the easiest and most economical way to control broomrape. The seeds of broomrape are very small, remaining

dormant for a long time, spreading very quickly and easily, which makes them difficult to control.

2.1.2. Cultivation of Trap and Catcher Plants

The trap plants release the stimulants necessary for the germination of the broomrape seed, allowing it to germinate, but the germinating broomrape dies before it clings to the roots of these plants. Thus, the amount of broomrape seeds in the soil is reduced with the use of trap plants. As a trap and catch crops linen (*Linum usitatissimum* L.) (Kleifeld et al., 1994; Qasem, 2019) and potential of some cereal (Kitiş et al., 2019) were studied. Overall, various study has shown that broomrape species show different degrees of virulence compared to the trap and catch plant. This method can be incorporated into an integrated parasitic weed control program to reduce the broomrape population and seed bank.

2.2. Physical Methods

2.2.1. Solarisation

Solarisation is used to eradicate many soil-borne diseases, pests and weed seeds with high temperature. A physical method called solarisation is used to control weeds. Numerous studies have shown that the correct solarisation application significantly reduces the broomrape seed bank (Sauerborn et al., 1989; Mauromicale et al., 2005; Mauro et al., 2015). Lombardo et al. (2012), also showed that the soil solarisation method in combination with fumigation improved the tomato yield and suppressed broomrape population.

2.2.2. Mulching

Mulching, another weed control method, is also a recommended method, especially for crops that will be planted in rows, such as tomatoes. If a mulch of the appropriate thickness is used, it will reduce the density of the broomrape in the future, as it prevents both an increase in the yield of the crop and the formation of seeds.

2.3. Chemical Methods

Chemical methods of combating broomrapes are limited due to the special live cycle and its haustorium, and the herbicide to be applied has a negative effect on the crop. In order to prove chemical control methods in broomrape, specific mechanisms of action must be introduced, which should be fatal for certain life stage such as haustorium formation or germination. Such a mode of action should then minimize the side effects for crops and environment (Eplee & Norris, 1987). In addition to chemical herbicides, biochemical herbicides from microorganisms or of plant origin are also used, described from many researches. For example, Fernández-Aparico et al. (2016), reported that the haustorium development of *Striga hermonthica, Orobanche crenata, Orobanche cumana* was reduced by the fungus *Diplodia cupressi* thanks to two toxins, namely Sphaeropsidone and Epi-sphaeropsidone. Some researcher indicates that salycilic asit (SA) application can improve resistance of the broomrape (Madany et al., 2020).

2.4. Biological Methods

Although there are many species of insects that feed on broomrape is *Phytomyza orobanchia* Kalt. (Diptera, Agromyzidae) is called. Klein & Kroschel (2001) described very well biological control of broomrape with *Phytomyza orobanchia* Kalt. They collected large number of phytophagous insects on broomrape. As a concept of biological weed control, it is important that biological control agents must be restricted to the one weed species. With this in mind, researchers found interesting *Phytomyza orobanchia* Kalt. The larval form of insect was found on the capsules and shoots of the broomrape. The effectiveness of this insect is reduced by the biotic and agronomic practices such as natural enemies, use of insecticides and low temperatures. From 500 to 1000 adults per hectare reduced more than 96% of the seed production of broomrape. Overall, just one broomrape control strategy is not economical and practical it should cover many strategies including biological control for beneficial insect in greenhouse, however, the intensive use of insecticides appears to be an obstacle.

In the biological control of *P. aegyptica,* researchers tested 88 actinobacterial strains against their antagonistic effects with plant pathogens. The effects of *Streptomyces pactum* Act12 strain on seed germination of *P. aegyptica* were evaluated in laboratory, greenhouse and field trials. The results reported that *S. pektum* Act12 strain inhibited the seed germination and germ tube elongation of broomrape more than 93%. On the other hand, in field trials, *S. pektum* Act12 reduced *P. aegyptica* emergence by 32.3% and increased tomato yield

by 57.1%. According to the results obtained that *S. pactum* Act12 will reduce the rate of parasitism in the control of *P. aegyptica* in tomato, as a result of decreasing the germination rate and coexistence with the microbiota in the roots of *P. aegyptica* (Chen et al., 2020).

Study of the endophytic bacteria with a large number of researches explored. Endophytic bacteria have relationships with host plants including mutualistic, symbiotic, commensalistic and trophobiotic, as well. Endophytic bacteria is able to improve plant growth, yield and can work like biocontrol agents that produce hormons, methobolits etc. (Ryan et al., 2008; Khan et al., 2020). Most of them live in the rhizosphere of the plant and some may be seed-borne endophytic bacteria. From this point of view, Matsumoto et al. (2021) indicated that *Sphingomonas melonis*, a seed-endophytic bacterium, accumulates in rice seeds and transmits the next generation to confer resistance to the rice (*Oryza sativa* L.) against pathogen *Burcholderia plantarii* by producing anthranilic acid (AA). This finding showed that seed-endophytic bacteria has a potential for threatened pathogen. To understand relationship between parasitic plant seed longevity, germination and the bacterial endophytes it can be interesting. Detection of bacterial endophytes associated with broomrape seeds can help understand the viability and germination of broomrape seeds. For example, Durlik et al. (2021) isolated two endophytic bacteria (*Brevibacterium frigoritolerans* and *Bacillus simplex*) within the *P. ramosa* seeds and three bacteria (*Bacillus cereus* group) from the

surface of the unsterile seeds. This knowledge should be kept in mind in order to have potential in the biological control of the broomrape.

3. BREEDING STRATEGIES FOR BROOMRAPE MANAGEMENT

3.1. Resistance Genes against Parasitic Weeds

Today's technology allows the identification of resistance genes or QTLs against weeds (Ramaiah, 1987; Scholes, 2008; Spallek, 2013). Mostly resistance against weeds is controlled by QTLs for example the resistance of *Striga* spp. is polygenic. However, resistance has some weaknesses, its efficiency can be changed with regard to environmental conditions. Moreover, even if the resistance of *S. gesnerioides* appears as monogenic, it relies on the *S. gesnerioides* race. On the other hand, resistance depends on the race of weeds. Furthermore, some receptors were used as an effective tool struggling with weeds. For instance, *CuRe* in tomato and *HaOr7* in sunflower they play a role in the PAMP-triggered immunity as a first level of plant defense responses (Jones & Dangl, 2006). Also, *CuRLR1* was identified as a resistance gene against to *Cuscuta campestris* (Jhu et al., 2020). In this context, wild types of crops are the most important resistance source against biotic stress factors. For this reason, the screening of wild types plays a crucial role in terms of plant breeding. For instance, although there is no still resistance source to some weeds such as *P. aegyptiaca*, Bai et al., 2020 carried out a project about this topic. Within the scope of the project, they screened 50 tomato accessions in order to resistance against one *P. aegyptiaca* species from China, the defensive cytological pathway

between the wild species and cultivar were evaluated, possible loci for *P. aegyptiaca* resistance in wild tomato types were identified and finally, candidate genes that are resistance to *P. aegyptiaca* were identified. For this purpose, *S. lycopersicum, S. chilense, S. habrochaites, S. pimpinellifolium, S. arcanum, S. corneliomulleri, S. glandulosum, S. minutum, S. chemielewskii, S. pennellii* accesions were used. In the result of the study, some resistance sources were identified in the wild tomato types. Especially, LA0716 accession was identified as tolerant and IL6-2 was determined as a potential line that has the major QTLs. These identified genes can pave the way for use in breeding programmes that are for the improvement of resistant varieties to *P. aegyptiaca.*

Numerous projects have been conducted for weed management for a long time. For this reason, one of the most important methods is the genetic engineering. In this context, some varieties that have Transgenes for bromoxynil, glyphosate, and glufosinate resistance are commercially available today. For example, Glyphosate-resistant crops have beneficial effects on weed management by reducing costs, improving flexibility and efficiency. Moreover, they have some advantages on the environment by reducing herbicide usage. These types of production activity are more ecologist and cost-effective. Furthermore, the capacity of phytotoxins production (allelopathy) is one of the most important weed management topics. The improvement of allelopathic plants is a complex topic because allelopathy is

controlled by multiple genes. Therefore, biotechnological methods are useful.

In this context there are 2 main strategies; firstly, the enhancement of allelochemicals production that is already present in plants and secondly insertion of new function to plant genome (Duke et al., 2002). It can be said that there are many methods that can be used within the scope of biotechnology. These methods can be collected under the two main titles as QTL mapping and genetic engineering. Within this framework, while QTL mapping is used for resistant gene/genes that can be used in weed management, genetic engineering is utilized for some breeding strategies such as gene insertion, gene silencing or alteration of gene function.

CONCLUSION

In agricultural areas, weeds cause both yield and quality losses, as well as host diseases and pests. Densities of weeds should be kept at tolerable levels. The increase in the world population and the fact that food production should increase in parallel means that the pressure on natural resources is increasing. It can be thought that weeds compete with cultivated plants in terms of water and nutrients and indirectly increase the pressure on natural resources. In order to reduce this pressure, chemical control with weeds has gained importance especially in recent years due to its ease of application and rapid effect. However, considering the negative effects of chemical control on both human and environmental health, it is necessary to develop and implement

alternative and more sustainable and environmentally friendly control methods. A more detailed understanding of the relationship between parasitic weeds and the host plant will enable the development of appropriate control methods.

REFERENCES

Aksoy, E.A. & Uygur, F.N. (2008). Effect of broomrapes on tomato and faba bean crops. Turkish Journal of Weed Science, 11(1): 1-7.

Babiker, A.G.T., Ahmed, E.A., Dawoud, D.A., & Abdella, N.K. (2007). *Orobanche* species in Sudan: History, distribution and management. Sudan Journal of Agricultural Research, 10: 107-114.

Bai, J., Wei, Q., Shu, J., Gan, Z., Li, B., Yan, D., ... & Li, J. (2020). Exploration of resistance to *Phelipanche aegyptiaca* in tomato. Pest Management Science, 76(11): 3806-3821.

Bergougnoux, V. (2014). The history of tomato: from domestication to biopharming. Biotechnology Advances, 32(1), 170-189.

Capinera, J.L. (2005). Relationships between insect pests and weeds: An evolutionary perspective. Weed Science, 53(6): 892-901.

Chen, J., Xue, Q.H., Ma, Y.Q., Chen, L.F., & Tan, X.Y. (2020). *Streptomyces pactum* may control *Phelipanche aegyptiaca* in tomato. Applied Soil Ecology, 146. https://doi.org/ARTN 103369 10.1016/j.apsoil.2019.103369

Cordas, D.I. (1973). Effects of Branched Broomrape on Tomatoes in California Fields. Plant Disease Reporter. ISSN: 0032-0811:926-927.

Dorais, M., Ehret, D.L., & Papadopoulos, A.P. (2008). Tomato (*Solanum lycopersicum*) health components: from the seed to the consumer. Phytochemistry Reviews, 7(2): 231-250.

Duffus, J.E. (1971). Role of weeds in the incidence of virus diseases. Annual Review of Phytopathology, 9(1): 319-340.

Duke, S.O., Scheffler, B.E., Dayan, F.E., & Dyer, W.E. (2002). Genetic engineering crops for improved weed management traits. In Crop Biotechnology ACS Symposium Series Vol. 829, Chapter 6, pp: 52-66.

Durlik, K., Żarnowiec, P., Piwowarczyk, R., & Kaca, W. (2021). Culturable endophytic bacteria from *Phelipanche ramosa* (Orobanchaceae) seeds. Seed Science Research, 31(1): 69-75.

Eplee, R.E., & Norris, R.S. (1987). Chemical control of *Striga*. Parasitic weeds in agriculture. Volume I. 173-182.

FAO, (2019). Tomato Production in 2019, Crops/Regions/World list/Production Quantity (pick lists). UN Food and Agriculture Organization, Corporate Statistical Database (FAOSTAT). 2020. Retrieved 2 september 2021.

Fernández-Aparicio, M., Masi, M., Maddau, L., Cimmino, A., Evidente, M., Rubiales, D., & Evidente, A. (2016). Induction of haustorium development by sphaeropsidones in radicles of the parasitic weeds *Striga* and *Orobanche*. A structure–activity relationship study. Journal of Agricultural and Food Chemistry, 64(25): 5188-5196.

Jenkins, J.A. (1948). The origin of the cultivated tomato. Economic Botany, 2(4): 379-392.

Jhu, M.Y., Farhi, M., Wang, L., Philbrook, R.N., Belcher, M.S., Nakayama, H., ... & Sinha, N.R. (2020). Lignin-based resistance to *Cuscuta campestris* parasitism in Heinz resistant tomato cultivars. bioRxiv, 706861.

Jones, J.D. & Dangl, J.L. (2006). The plant immune system. Nature, 444(7117): 323-329.

Khan, S.S., Verma, V., & Rasool, S. (2020). Diversity and the role of endophytic bacteria: A review. Botanica Serbica, 44(2): 103-120.

Kitiş, Y.E., Grenz, J.H., & Sauerborn, J. (2019). Effects of some cereal root exudates on germination of broomrapes (*Orobanche* spp. and *Phelipanche* spp.). Mediterranean Agricultural Sciences, 32(2): 145-150.

Kleifeld, Y., Goldwasser, Y., Herzlinger, G., Joel, D. M., Golan, S., & Kahana, D. (1994). The effects of flax (*Linum usitatissimum* L.) and other crops as trap and catch crops for control of Egyptian broomrape (*Orobanche aegyptiaca* Pers.). Weed Research, 34(1): 37-44.

Klein, O. & Kroschel, J. (2002). Biological control of *Orobanche* spp. with *Phytomyza orobanchia*, A review. Biocontrol, 47(3): 245-277.

Lombardo, S.A.M.G., Longo, A.M.G., Monaco, A. L., & Mauromicale, G. (2012). The effect of soil solarisation and fumigation on pests and yields in greenhouse tomatoes. Crop Protection, 37: 59-64.

Madany, M.M., Obaid, W.A., Hozien, W., AbdElgawad, H., Hamed, B. A., & Saleh, A.M. (2020). Salicylic acid confers resistance against broomrape in tomato through modulation of C and N metabolism. Plant Physiology and Biochemistry, 147: 322-335.

Matsumoto, H., Fan, X., Wang, Y., Kusstatscher, P., Duan, J., Wu, S., & Wang, M. (2021). Bacterial seed endophyte shapes disease resistance in rice. Nature Plants, 7(1): 60-72.

Mauro, R.P., Monaco, A.L., Lombardo, S., Restuccia, A., & Mauromicale, G. (2015). Eradication of *Orobanche*/*Phelipanche* spp. seedbank by soil solarization and organic supplementation. Scientia Horticulturae, 193: 62-68.

Mauromicale, G., Monaco, A.L., Longo, A.M., & Restuccia, A. (2005). Soil solarisation, a nonchemical method to control branched broomrape (*Orobanche ramosa*) and improve the yield of greenhouse tomato. Weed Science, 53(6): 877-883.

Parker, C. (2013). The parasitic weeds of the Orobanchaceae. In *Parasitic Orobanchaceae* (pp. 313-344). Springer, Berlin, Heidelberg.

Qasem, J.R. (2019). Branched broomrape (*Orobanche ramosa* L.) control in tomato (*Lycopersicon esculentum* Mill.) by trap crops and other plant species in rotation. Crop Protection, 120: 75-83.

Ramaiah, K.V. (1987) Breeding Cereal Grains for Resistance to Witchweed. In: Musselman, L.J., Ed., Parasitic Weeds in Agriculture, Vol. 1: Striga, CRC Press, Boca Raton, 227-242.

Rich, J.R., Brito, J.A., Kaur, R., & Ferrell, J.A. (2009). Weed species as hosts of Meloidogyne: A review. Nematropica, 157-185.

Ryan, R.P., Germaine, K., Franks, A., Ryan, D.J., & Dowling, D.N. (2008). Bacterial endophytes: Recent developments and applications. FEMS microbiology letters, 278(1): 1-9.

Sauerborn, J., Linke, K.H., Saxena, M.C., & Koch, W. (1989). Solarisation; A physical control method for weeds and parasitic plants (*Orobanche* spp.) in Mediterranean agriculture. Weed Research, 29(6): 391-397.

Scholes, J.D. & Press, M.C. (2008). *Striga* infestation of cereal crops - an unsolved problem in resource limited agriculture. Current Opinion in Plant Biology, 11(2): 180-186.

Spallek, T., Mutuku, M., & Shirasu, K. (2013). The genus *Striga*: A witch profile. Molecular Plant Pathology, 14(9): 861-869.

van der Knaap, E., Chakrabarti, M., Chu, Y.H., Clevenger, J.P., Illa-Berenguer, E., Huang, Z., ... & Wu, S. (2014). What lies beyond the eye: The molecular mechanisms regulating tomato fruit weight and shape Frontiers in Plant Science, 5: 227.

Zimdahl, R.L. (2018). Weeds: The Beginning. Fundamentals of Weed Science. Academic Press, Elsevier, UK. pp: 17-46.

CHAPTER XV

AN OVERVIEW OF TURMERIC: PROPERTIES, CHEMICAL COMPOSITION, HEALTH EFFECTS AND USES IN FOODS

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INTRODUCTION

Plants of the genus *Curcuma* can include many taxonomic groups and are cultivated for medicinal, ornamental, cultural and economic purposes (Velayudhan et al., 2012). Turmeric (*Curcuma longa*) is an important spice that has been used in the cuisines of many countries for centuries to add flavor and color to foods (Tayyem et al., 2006; Munekata et al., 2021). The origin of the Latin name of turmeric comes from the Arabic "Kurkum". In Sanskrit, it is called "Haridra" meaning yellow, "Gauri" meaning bright, and "Kanchani" meaning goddess of gold (Naidu & Suresh, 2018). Originally used as a dye due to its bright yellow color, turmeric also holds a special place in religious rituals (Nair, 2013a; Gayathiri & Narendhiran, 2020).

Turmeric, also called Indian saffron due to its orange-yellow color, has been used in India since ancient times according to ethnobotanical evidence (Prasad & Aggarwal, 2011; Velayudhan et al., 2012; Madhusankha et al., 2019). It is thought that turmeric first spread from India to Asian countries, then arrived in East Africa in the ninth century and West Africa in the thirteenth century (Roy et al., 2014). Today, it is grown in almost all Asian countries, especially India, Myanmar and Thailand, Nigeria, South America, and the Pacific islands (Nair, 2013a). Worldwide production of turmeric is approximately 1,100,000 tons per year (Gopi et al., 2019). Still, the largest turmeric producer (around 80%) and exporter is India (Prasad & Shivay, 2021).

Turmeric has a wide range of uses including dairy products, baked products, cake icings, biscuits, salad dressings, popcorn, cereals, sauces, sweets, gelatins and drinks (Bhowmik et al., 2009; Prasad & Aggarwal, 2011). In addition to its flavor and color effect, its use in functional food production is being investigated due to the bioactive compounds it contains (Zou et al., 2016).

Turmeric is the most widely known species of *Curcuma* and it is a cultivated plant grown in a temperate climate in many parts of the world (Sharifi-Rad et al., 2020). Turmeric can also be used alone or in combination with other spices in foods (Tayyem et al., 2006).

In addition to being used as a spice, some pharmacological activities of turmeric are known such as antioxidant, anti-inflammatory, antimutagenic, anticancer, antidiabetic, and hepatoprotective effects (Chattopadhyay et al., 2004; Krup et al., 2013; Ahmad et al., 2020). These effects are associated with the presence of bioactive compounds known as curcuminoids. It is stated that these health benefits are mainly linked to curcumin which is the main compounds of curcuminoids (Rathaur et al., 2012; Munekata et al., 2021). As a result, numerous studies have indicated that turmeric has many medicinal properties. Also, turmeric is widely used in different cosmetic products as an ingredient such as creams, lotions, face packs, etc. (Bhowmik et al., 2009; Krup et al., 2013).

In this book chapter, it is aimed to give general information about some properties of the turmeric plant, chemical compositions, health effects, and usage areas in the food industry.

1. GENERAL PROPERTIES OF TURMERIC

Curcuma longa or turmeric is the species of the genus *Curcuma* in the Zingiberaceae family which is an important family of the Zingiberales order (Chattopadhyay et al., 2004; ur Rehman et al., 2009, Rahaman et al., 2021). Important spices such as cardamom and ginger are also included in the Zingiberaceae family (Nair, 2013b).

Turmeric is a perennial herb that can reach 100 cm in height. The oblong palmate leaves are arranged in two rows. These leaves are then divided into the leaf sheath, which in turn forms the false stem, petiole, and leaf blade (Kumar et al., 2017). The plants have cylindrical rhizomes 2.5-7.0 cm in length and approximately 2.5 cm in diameter, varying in color from yellow to orange (Prasad & Aggarwal, 2011; Kumar et al., 2017). A leafy shoot has an average of 6-10 leaves. The main plant part of turmeric used is its rhizomes. It consists of the main rhizome and finger-shaped side branches. It is also sold in the market in the form of rhizome. There are 7-12 nodes in mature mother rhizomes (Nair, 2013b). The primary rhizome is usually pear-shaped and may also be called a “bulb”, and the secondary rhizome is cylindrical (Ahmad et al., 2010). The flowers, which are yellow and 10-15 cm long, are grouped in a dense spike-like shape (Kumar et al., 2017). The flowering of turmeric begins 109-155 days after planting. Both the variety and climatic conditions can alter the flowering pattern of

turmeric (Nair, 2013b). The turmeric plant can be grown in a warm and humid climate within the temperature range of 20-40 °C (Lal, 2012; Kumar et al., 2017).

The large, concave bracts of *Curcuma* spp. are considered their showiest feature and are used as pot plants and cut flowers because they have a lifespan of more than 3-4 weeks after harvest. Studies on *Curcuma* spp. are generally related to *Curcuma longa* and *Curcuma angustifolia*, which have economic value. Some *Curcuma* species are produced as cut flowers due to their showy brackets and long post-harvest vase life, while some dwarf forms of *Curcuma* species are grown as pot plants (Roh et al., 2006).

2. CHEMICAL COMPOSITION OF TURMERIC

In terms of chemical composition, turmeric contains 6.3% protein, 69.4% carbohydrates, 5.1% fat 13.1% moisture and 3.5% minerals (Chattopadhyay et al., 2004; Prasad & Aggarwal, 2011; Purnomo et al., 2018). Furthermore, it contains vitamins such as pyridoxine, niacin, folates, vitamin C (Ahmad et al., 2020). Curcuminoids are the most well-known main components of turmeric. Curcumin, demethoxycurcumin, and bisdemethoxycurcumins are the three main curcuminoid compounds (Kotra et al., 2019; Monton et al., 2019). In most studies, it is stated that raw turmeric contains only 3-5% curcuminoids in general. Curcumin has a low-molecular weight (368.37 g/mol) and it is the main polyphenol derived from the turmeric (Zaki Ahmad et al., 2014; Hewlings & Kalman, 2017).

The rate of curcumin in turmeric could vary depending on the cultivation, the soil, and climatic conditions in which it is grown (Kotra et al., 2019).

It is reported that curcumin ($C_{21}H_{20}O_6$) was first isolated from *Curcuma longa* rhizomes by Vogel and Pelletier and these extracts, referred to as a "yellow substance", later became known as curcumin. Its chemical structure was defined in 1910 and chemical synthesis was confirmed in 1913 (Aggarwal et al., 2005; Gadekar et al., 2020).

Many studies are evaluating the effect of traditional and new extraction technologies used for the extraction of curcuminoids. Solvent properties have a significant effect on the extraction yield. Since curcuminoids have poor solubility in water, organic solvents such as ethanol and acetone should be used. The influence of variables such as solid/solvent ratio, solvent composition, particle size, extraction time, temperature, and ultrasound frequency is also important in extraction (Munekata et al., 2021).

The main components of turmeric essential oil have been reported as ar-turmerone (43-49%), curlone (17-18%), and turmerone (13-16%) by Monton et al., 2019. Essential oil components are affected by drying conditions, convection, and microwave time (Monton et al., 2019). Freeze drying causes less damage to bioactive components (curcuminoids, phenolic acids, flavonoids) and antioxidant activity compared to hot drying methods (Chumroenphat et al., 2021). Many

compounds have been described in several reports, including sesquiterpene hydrocarbons, monoterpene hydrocarbons, oxygenated monoterpenes, and oxygenated sesquiterpenes (Jayaprakasha et al., 2005). The chemical structures of important turmeric components are shown in Figure 1 (Amalraj et al., 2017a).

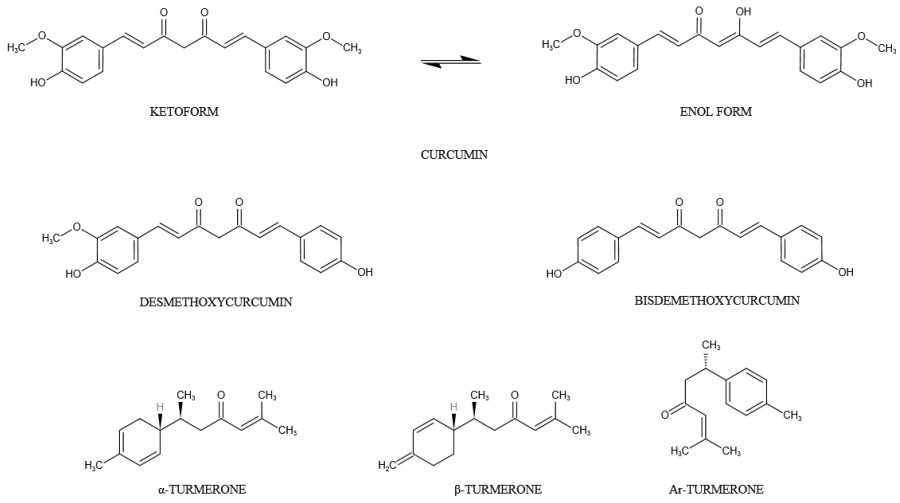

Figure 1: Chemical Structures of Important Turmeric Components (Amalraj et al., 2017a)

3. HEALTH EFFECTS OF TURMERIC

Natural products have been used in traditional medicines as therapeutic and health promoters for thousands of years. Curcuminoids are also used in the treatment of metabolic diseases thanks to their bioactive components and almost no side effects.

Table 1: Effects of Turmeric in Various Diseases

Diseases	Subjects	Dose	Effects	References
Coronary Artery Disease (CAD)	33 patients with CAD	500 mg/day curcumin for 8 weeks	Significant decrease in serum levels of triglycerides, LDL-cholesterol and VLDL-cholesterol	(Mirzabeigi et al., 2015)
Diabetes	80 diabetic patients	80 mg/day nano-curcumin for 8 weeks	Significant reduction in HbA1c and fasting blood sugar levels	(Asadi et al., 2019)
	53 diabetic patients	1500 mg/day curcumin for 10 weeks	Significant reduction in waist circumference and fas ting blood sugar level	(Hodaei et al., 2019)
Polycystic Ovarian Syndrome (PCOS)	72 patients with PCOS	1500 mg/day curcumin for 3 months	Significant increase in gene expression of PGC1α and activity of the Gpx enzyme	(Heshmati et al., 2020)
	60 patients with PCOS	500 mg/day curcumin for 12 weeks	Significant decrease in weight, BMI, fasting glucose, serum insulin, insulin resistance, and total cholesterol	(Jamilian et al., 2020)
Metabolic Syndrome	44 elderly females with metabolic syndrome	80 mg/day nano-curcumin for 6 weeks	Significant increase in brain-derived neurotrophic factor (BDNF) and IL-10. significant decrease in IL-6 serum levels	(Osali, 2020)
Arthritis	50 patients with knee osteoarthritis	180 mg/day curcumin for 8 weeks	Significant decrease in the knee pain visual analog scale scores	(Nakagawa et al., 2014)
	36 rheumatoid arthritis patients	250 or 500 mg/day curcumin for 90 days	Significant improvement in C-reactive protein (CRP), rheumatoid factor values, and erythrocyte sedimentation rate	(Amalraj et al., 2017b)
Mental Disorders	38 patients with chronic schizophrenia	3000 mg/day curcumin combined with antipsychotics for 2 years	Significant response to curcumin within 6 months in total Positive and Negative Symptoms Scale	(Miodownik et al., 2019)
	56 major depressive disorder patients	1000 mg/day curcumin for 8 weeks	Significant improvement in Inventory of Depressive Symptomatology self-rated version (IDS-SR_{30}) total and mood score	(Lopresti et al., 2014)

Curcuminoids and its derivatives have a wide variety of biological activities, including antioxidant, antimicrobial, antimalarial, anti-inflammatory, anticancer, cardioprotective, neuroprotective, and radioprotective effects (Kumar et al., 2017; Amalraj et al., 2017a). Oral curcumin supplements; improves overall health-related quality of life in patients with various health problems such as cancer and migraine especially in short-term intervention studies (Sadeghian et al., 2021).

In this section, the effects of turmeric on cardiovascular diseases, diabetes, metabolic syndrome, inflammatory diseases, mental diseases, and cancer are discussed. Recommended doses of use and various health effects are summarized in Table 1.

3.1. Cardiovascular Diseases

Cardiovascular diseases (CVD) are common all over the world and are considered the cause of early (premature) death. The most common diseases in this group are ischemic heart disease and stroke (Roth et al., 2017). CVD is associated with dyslipidemia, high pro-thrombotic factors, insufficient physical activity, high blood pressure, high homocysteine levels, obesity, tobacco consumption, and stress. To reduce the risk of developing CVDs, not only people in the high risk group but also healthy individuals should avoid harmful habits and follow healthy lifestyle recommendations (Munekata et al., 2021).

It is stated that overproduction of reactive oxygen species (ROS) may affect the formation of some CVD species. The imbalance between oxidant-antioxidant systems can cause excessive ROS production.

Therefore, natural antioxidant applications are thought to reduce or prevent the progression of CVDs. There are several specific receptors and developed intracellular mechanisms against extracellular stimuli in the cardiovascular system. Curcuminoids are thought to support these mechanisms (Pourbagher-Shahri et al., 2021).

The mechanisms of action of curcuminoids against CVDs are regulation of oxidative stress, anti-inflammatory activity, and suppression of apoptosis. As a result of previous studies on oxidative stress, it is stated that curcuminoids are effective in inducing the endogenous antioxidant enzymes activity, could retard the formation of ROS, and maintain the mitochondrial redox potential and function (Munekata et al., 2021).

Curcumin can improve CVDs such as cardiac hypertrophy, myocardial infarction, cardiac fibrosis, atherosclerosis, heart failure, and ischemia. Potential molecular mechanisms underlying their cardioprotective effects are AMPK, mTOR, PI3k/Akt, JAK/STAT, NF-κB, Nrf2, MAPK, Notch, PPARs and their regulatory effects on arachidonic signaling pathways. It is also reported that curcumin may exert cardioprotective effects by modulating toll-like receptors (Pourbagher-Shahri et al., 2021).

3.2. Diabetes Mellitus

The diabetes mellitus is a chronic metabolic disease that results in altered carbohydrate, fat, and protein metabolism due to the inability of the body to produce insulin or to use it properly (Rivera-Mancía et al.,

2018). Effective treatment strategies are being developed against diabetes mellitus, pancreatic β-cell dysfunction and insulin resistance through lifestyle changes, pharmacological and surgical interventions (McLellan et al., 2014). As an alternative to existing diabetes medications, curcumin has attracted attention in the last decade due to its anti-diabetic properties. There is a lot of research, especially in animal models and in vitro (Rivera-Mancía et al., 2018).

Possible mechanisms of curcuminoids action in diabetes management; glucose metabolism changes, regulation of oxidative stress, and anti-inflammatory activity. Curcuminoids can improve insulin resistance by reducing hepatic glucose production, increasing GLUT2, GLUT3, and GLUT4 gene expression, increasing AMP kinase activation and inducing insulin receptor substrate 1 (IRS1) level, which increases glucose absorption (Ghorbani et al., 2014). Besides, it is reported that they can inhibit the phosphoenolpyruvate carboxykinase, glucose-6-phosphatase, and essential gluconeogenesis enzymes. It is stated that curcuminoids also have effects such as inducing the endogenous antioxidant enzymes activity and reducing peroxidation of plasma lipids (Munekata et al., 2021).

3.3. Metabolic Syndrome

Metabolic syndrome is a health problem that consists of a combination of various diseases such as cardiovascular diseases, insulin resistance, dyslipidemia, obesity, and high blood pressure. Risk factors associated with this syndrome include unbalanced and malnutrition, reduced

physical activity, fat around the waist, high LDL and low HDL levels, and insulin resistance (Samson & Garber, 2014). Curcuminoids; can help eliminate these risk factors by affecting oxidative stress, glucose and fat metabolism, and inflammatory processes. The mechanisms of action mentioned in recent studies are: inhibiting tumor necrosis factor-α synthesis, lowering serum alanine aminotransferase and aspartate aminotransferase levels, reducing oxidative stress, and inducing catalase activity (Munekata et al., 2021).

3.4. Arthritis

Arthritis has a high prevalence worldwide and is defined as inflammation of the joints. The most common of arthritis with more than 100 subtypes are osteoarthritis, psoriatic arthritis, rheumatoid arthritis, and inflammatory arthritis (Tang, 2019). Curcumins alter NF-κB signals and proinflammatory cytokines (phospholipase A2, COX-2, and 5-LOX activities, and interleukin production). Thus, they can help manage arthritis by reducing pain, swelling, and tenderness in joints and by inducing an anti-inflammatory response (Daily et al., 2016).

3.5. Inflammatory Bowel Diseases

It is characterized by inflammatory bowel diseases, chronic intestinal inflammation such as Chron's disease, and ulcerative colitis (Rubin et al., 2012). It is stated that due to its anti-inflammatory properties, turmeric has the potential to cure these diseases. Besides, studies are showing that it is effective in other gastrointestinal system disorders such as *Helicobacter pylori* infection and peptic ulcer (Hay et al., 2019).

3.6. Mental Disorders

Curcuminoids can help manage mental disorders and improve mental states by modulating key molecules. The effective mechanism may vary according to the type of mental illness. In depression, modulation of dopamine and serotonin production, inhibition of monoamine oxidase release, and neurotrophic factors can be effective in improving neuroinflammation. In the case of schizophrenia, curcumin is known to improve the oxidative state and mitochondrial function by modulating mitochondrial complex II activity, membrane potential, and ATP level (Munekata et al., 2021).

Various reactions such as inflammation, glutamatergic toxicity, mitochondrial activity, activation of apoptosis pathways, and dysfunction of the ubiquitin/proteasome system, the elevation of nitric oxide and iron, and change in the homeostasis of antioxidants play a role in the pathogenesis of neurodegenerative diseases. *Curcumin* can affect these mechanisms and provide a therapeutic effect (Amalraj et al., 2017a).

3.7. Cancer

The use of turmeric alone or in combination with other drugs is a promising application for cancer treatment. Its effect in cancer treatment seems to be mostly due to the antioxidant and anti-inflammatory effects of curcumin. This compound, the main component of turmeric, exhibits anticancer activity by altering different cell signaling pathways, including growth and transcription factors,

cytokines, genes that modulate apoptosis and cellular proliferation (Giordano & Tommonaro, 2019).

4. USES OF TURMERIC IN FOODS

Synthetic preservatives with antimicrobial and antioxidant properties are widely used to preserve shelf life in foods. However, in recent years, natural preservatives have been investigated as an alternative to these synthetic preservatives (Demirhan, 2020). It has an antioxidant and antimicrobial effect owing to the important bioactive compounds contained in some herbal extracts, spices, and essential oils (Mahmud & Khan, 2018). Turmeric powder has a bright yellow color (Figure 2) and it is used as a spice and food coloring in the food industry (Madhusankha et al., 2019).

Figure 2: Commercial *Curcuma longa* Rhizomes and Powder
(Original by Er Demirhan)

Table 2: Current Studies Investigating the Use of Turmeric in Foods

Dose	Foods	Results	Reference
0, 0.1, 0.2 and 0.3% turmeric powder	Soft cheese	As the turmeric concentration increased, the total number of bacteria decreased. There was no significant difference in texture, bitterness and color.	(Al-Obaidi, 2019)
250, 500 and 750 mg/kg turmeric extract	Fresh lamb sausages with modified atmosphere-packaged	The antioxidant capacity is increased and lipid oxidation decreased in sausages. Physical-chemical parameters were not affected except the color.	(de Carvalho et al., 2020)
0.2 g curcumin/100 g oleojel	Pork burgers	Oleogels containing curcumin have been used as an alternative to animal fat. Lipid oxidation is reduced. However, the color change was observed that negatively affected acceptability	(Gómez-Estaca et al., 2020)
1% turmeric extract	Biscuits	Good antioxidant effect compared to synthetic antioxidants	(Hefnawy et al., 2016)
0, 2, 4, 6, 8 and 10% turmeric powder	Snacks developed from broken rice grains	It has been stated that although up to 6% of turmeric powder causes physical changes, it does not affect consumer acceptance.	(Ribeiro Oliveira et al., 2020)
1, 3, 5, 10, 20 mg/ml turmeric extract nanoemulsion	Milk	There was no significant change in the aroma. However, its use in high concentrations affects the color. The curcumin content remained stable over the 21-day storage period.	(Park et al., 2019)
10 to 50 g/kg flour mixture	Pasta with whole wheat flour	The antioxidant capacity and total phenolic content of pasta with turmeric were found to be high. It is also stated that it provides a natural color.	(Wahanik et al., 2018)
2 and 4% turmeric powder	Meatballs	It was stated that the total Aerobic Bacteria numbers were lower than the control group and the Total Coliform Bacteria numbers of the group containing 4% turmeric were lower than the control group.	(Demirhan, 2020)
0.5% turmeric extract	Cuttlefish	It has been reported to control psychrophilic, mesophilic and *Pseudomonas* bacterial growth and delay the formation of biogenic amines.	(Arulkumar et al., 2017)

The poor water solubility of curcuminoids is a concern for their use in functional food production. Because these compounds will have poor solubility and absorption in the intestinal tract. Therefore, the production of emulsified systems that facilitate the dispersion of curcuminoids in an aqueous environment will be important to increase the bioavailability of curcuminoids (Munekata et al., 2021).

Studies investigating the use of turmeric in meat products, dairy products, cereals, and beverages are summarized in Table 2. While these natural compounds generally act to retard microbial growth and increase antioxidant capacity, they do not significantly affect the physical and chemical properties of the food. However, it affects sensory properties such as color and taste.

CONCLUSION

Turmeric is a plant of highly medicinal and economical value. Furthermore, it is important spice, food coloring and natural food preservative and it has been widely used in foods for many years. In some studies, it is stated that turmeric has beneficial effects on health due to its important bioactive compounds. However, it is necessary to see the results of larger-scale and long-term intervention studies to give definitive recommendations. There are important studies on its use as a natural preservative, colorant, and health promoter in foods. However, studies are needed to explain sufficient turmeric concentration to achieve the desired effect and examine the stability of bioactive ingredients during processing and storage.

REFERENCES

Aggarwal, B.B., Kumar, A., Aggarwal, M.S., & Shishodia, S. (2005). Curcumin derived from turmeric (*Curcuma longa*): a spice for all seasons. Phytopharmaceuticals in Cancer Chemoprevention, 23: 351-87.

Ahmad, R.S., Hussain, M.B., Sultan, M.T., Arshad, M.S., Waheed, M., Shariati, M.A., ... & Hashempur, M.H. (2020). Biochemistry, safety, pharmacological activities, and clinical applications of turmeric: a mechanistic review. Evidence-based complementary and alternative medicine, Available from https://doi.org/10.1155/2020/7656919

Ahmad, W., Hassan, A., Ansari, A., & Tarannum, T. (2010). *Cucurma longa* L.- A review. Hippocratic Journal of Unani Medicine, 5: 179-190.

Al-Obaidi, L.F.H. (2019). Effect of adding different concentrations of turmeric powder on the chemical composition, oxidative stability and microbiology of the soft cheese. Plant Archives, 19: 317-321.

Amalraj, A., Pius, A., Gopi, S., & Gopi, S. (2017a). Biological activities of curcuminoids, other biomolecules from turmeric and their derivatives – A review. Journal of Traditional and Complementary Medicine, 7: 205-233.

Amalraj, A., Varma, K., Jacob, J., Divya, C., Kunnumakkara, A.B., Stohs, S.J., & Gopi, S. (2017b). A novel highly bioavailable curcumin formulation improves symptoms and diagnostic indicators in rheumatoid arthritis patients: A randomized, double-blind, placebo-controlled, two-dose, three-arm, and parallel-group study. Journal of Medicinal Food, 20(10): 1022-1030.

Arulkumar, A., Ramanchandran, K., Paramasivam, S., Palanivel, R., & Miranda, J.M. (2017). Effects of turmeric (*Curcuma longa*) on shelf life extension and biogenic amine control of cuttlefish (*Sepia brevimana*) during chilled storage. CyTA - Journal of Food, 15(3): 441-447.

Asadi, S., Gholami, M. S., Siassi, F., Qorbani, M., Khamoshian, K., & Sotoudeh, G. (2019). Nano curcumin supplementation reduced the severity of diabetic sensorimotor polyneuropathy in patients with type 2 diabetes mellitus: A randomized double-blind placebo- controlled clinical trial. Complementary Therapies in Medicine, 43: 253-260.

Bhowmik, D.C., Kumar, K.S., Chandira, M., & Jayakar, B. (2009). Turmeric: A herbal and traditional medicine. Archives of Applied Science Research, 1(2): 86-108.

Chattopadhyay, I., Biswas, K., Bandyopadhyay, U., & Banerjee, R.K. (2004). Turmeric and curcumin: Biological actions and medicinal applications. Current Science, 44-53.

Chumroenphat, T., Somboonwatthanakul, I., Saensouk, S., & Siriamornpun, S. (2021). Changes in curcuminoids and chemical components of turmeric (*Curcuma longa* L.) under freeze-drying and low-temperature drying methods. Food Chemistry, 339: 128121.

Daily, J.W., Yang, M., & Park, S. (2016). Efficacy of turmeric extracts and curcumin for alleviating the symptoms of joint arthritis: A systematic review and meta-analysis of randomized clinical trials. Journal of Medicinal Food, 19: 717-729.

de Carvalho, F.A.L., Munekata, P.E.S., Lopes de Oliveira, A., Pateiro, M., Domínguez, R., Trindade, M.A., & Lorenzo, J.M. (2020). Turmeric (*Curcuma longa* L.) extract on oxidative stability, physicochemical and sensory properties of fresh lamb sausage with fat replacement by tiger nut (*Cyperus esculentus* L.) oil. Food Research International, 136: 109487.

Demirhan, B. (2020). The effect of turmeric on microbial quality in meatballs. Harran Tarım ve Gıda Bilimleri Dergisi, 24(1): 9-16.

Gadekar, A., Edake, G., & Ubale, A. (2020). Medicinal use of *Curcuma*: a review. Current Trends in Pharmacy and Pharmaceutical Chemistry, 2(4): 26-31.

Gayathiri, M. & Narendhiran, V. (2020). Best organic media for growing turmeric minisetts in protray nursery. Plant Archives, 20(1): 3014-3016.

Ghorbani, Z., Hekmatdoost, A., & Mirmiran, P. (2014). Anti-hyperglycemic and insulin sensitizer effects of turmeric and its principle constituent curcumin.

International Journal of Endocrinology and Metabolism, 12(4): e18081.

Giordano, A. & Tommonaro, G. (2019). Curcumin and cancer. Nutrients, 11: 2376.

Gómez-Estaca, J., Pintado, T., Jiménez-Colmenero, F., & Cofrades, S. (2020). The effect of household storage and cooking practices on quality attributes of pork burgers formulated with PUFA- and curcumin-loaded oleogels as healthy fat substitutes. LWT, 119: 108909.

Gopi, S., Amalraj, A., Jude, S., Benson, K.T., Balakrishnan, P., Haponiuk, J.T., & Thomas, S. (2019). Isolation and characterization of stable nanofiber from turmeric spent using chemical treatment by acid hydrolysis and its potential as antimicrobial and antioxidant activities. Journal of Macromolecular Science, Part A, 56(4): 327-340.

Hay, E., Lucariello, A., Contieri, M., Esposito, T., De Luca, A., Guerra, G., & Perna, A. (2019). Therapeutic effects of turmeric in several diseases: An overview. Chemico-Biological Interactions, 310: 108729.

Hefnawy, H.T., El-Shourbagy, G.A., & Ramadan, M.F. (2016). Phenolic extracts of carrot, grape leaf and turmeric powder: antioxidant potential and application in biscuits. Journal of Food Measurement and Characterization, 10(3): 576-583.

Heshmati, J., Golab, F., Morvaridzadeh, M., Potter, E., Akbari-Fakhrabadi, M., Farsi, F., & Shidfar, F. (2020). The effects of curcumin supplementation on oxidative stress, Sirtuin-1 and peroxisome proliferator activated receptor γ coactivator 1α gene expression in polycystic ovarian syndrome (PCOS) patients: A randomized placebo-controlled clinical trial. Diabetes and Metabolic Syndrome: Clinical Research and Reviews, 14(2): 77-82.

Hewlings, S.J. & Kalman, D.S. (2017). Curcumin: a review of its effects on human health. Foods, 6(10): 92.

Hodaei, H., Adibian, M., Nikpayam, O., Hedayati, M., & Sohrab, G. (2019). The effect of curcumin supplementation on anthropometric indices, insulin resistance and oxidative stress in patients with type 2 diabetes: A randomized, double-blind clinical trial. Diabetology and Metabolic Syndrome, 11(1): 41.

Jamilian, M., Foroozanfard, F., Kavossian, E., Aghadavod, E., Shafabakhsh, R., Hoseini, A., & Asemi, Z. (2020). Effects of curcumin on body weight, glycemic control and serum lipids in women with polycystic ovary syndrome: A randomized, double-blind, placebo-controlled trial. Clinical Nutrition ESPEN, 36: 128-133.

Jayaprakasha, G.K., Jagan Mohan Rao, L., & Sakariah, K.K. (2005). Chemistry and biological activities of *C. longa.* Trends in Food Science and Technology, 16: 533-548.

Kotra, V.S.R., Satyabanta, L., & Goswami, T.K. (2019). A critical review of analytical methods for determination of curcuminoids in turmeric. Journal of Food Science and Technology, 56(12): 5153-5166.

Krup, V., Prakash, L.H., & Harini, A. (2013). Pharmacological activities of turmeric (*Curcuma longa* Linn): a review. J. Homeop Ayurv Med, 2(133): 2167-1206.

Kumar, A., Singh, A.K., Kaushik, M.S., Mishra, S.K., Raj, P., Singh, P.K., & Pandey, K.D. (2017). Interaction of turmeric (*Curcuma longa* L.) with beneficial microbes: A review. 3 Biotech, 7(6): 357.

Lal, J. (2012). Turmeric, curcumin and our life: a review. Bull Environ Pharmacol Life Sci, 1(7): 11-17.

Lopresti, A.L., Maes, M., Maker, G.L., Hood, S.D., & Drummond, P.D. (2014). Curcumin for the treatment of major depression: A randomised, double-blind, placebo controlled study. Journal of Affective Disorders, 167: 368-375.

Madhusankha, G.D.M.P., Thilakarathan, R.C.N., Liyanage, T., & Navaratne, S.B. (2019). Compositional analysis of turmeric types cultivated in Sri Lanka and India. International Journal of Herbal Medicine, 7(1): 35-38.

Mahmud, J. & Khan, R.A. (2018). Characterization of natural antimicrobials in food system. Advances in Microbiology, 8(11): 894.

McLellan, K.C.P., Wyne, K., Villagomez, E.T., & Hsueh, W.A. (2014). Therapeutic interventions to reduce the risk of progression from prediabetes to type 2 diabetes mellitus. Therapeutics and Clinical Risk Management, 10: 173.

Miodownik, C., Lerner, V., Kudkaeva, N., Lerner, P.P., Pashinian, A., Bersudsky, Y., & Bergman, J. (2019). Curcumin as add-on to antipsychotic treatment in patients with chronic schizophrenia: A randomized, double-blind, placebo-controlled study. Clinical Neuropharmacology, 42(4): 117-122.

Mirzabeigi, P., Mohammadpour, A.H., Salarifar, M., Gholami, K., Mojtahedzadeh, M., & Javadi, M.R. (2015). The effect of curcumin on some of traditional and non-traditional cardiovascular risk factors: A pilot randomized, double-blind, placebo-controlled trial. Iranian Journal of Pharmaceutical Research, 14(2): 479-486.

Monton, C., Luprasong, C., & Charoenchai, L. (2019). Convection combined microwave drying affect quality of volatile oil compositions and quantity of curcuminoids of turmeric raw material. Revista Brasileira de Farmacognosia, 29(4): 434-440.

Munekata, P.E.S., Pateiro, M., Zhang, W., Dominguez, R., Xing, L., Fierro, E.M., & Lorenzo, J.M. (2021). Health benefits, extraction and development of functional foods with curcuminoids. Journal of Functional Foods, 79: 104392.

Naidu, D.S., & Suresh, D.A. (2018). Effects of turmeric (*Curcuma longa*) in dentistry. International Journal of Development Research, 8(07): 21828-21831.

Nair, K.P.P. (2013a). Turmeric. In The Agronomy and Economy of Turmeric and Ginger, pp. 1–5. Available from https://doi.org/10.1016/B978-0-12-394801-4.00001-6

Nair, K.P.P. (2013b). The Botany of Turmeric. In The Agronomy and Economy of Turmeric and Ginger, pp. 7–32. Available from https://doi.org/10.1016/b978-0-12-394801-4.00002-8

Nakagawa, Y., Mukai, S., Yamada, S., Matsuoka, M., Tarumi, E., Hashimoto, T., & Nakamura, T. (2014). Short-term effects of highly-bioavailable curcumin for treating knee osteoarthritis: a randomized, double-blind, placebo-controlled prospective study. Journal of Orthopaedic Science, 19(6): 933–939.

Osali, A. (2020). Aerobic exercise and nano-curcumin supplementation improve inflammation in elderly females with metabolic syndrome. Diabetology and Metabolic Syndrome, 12(1): 26.

Park, S.J., Hong, S.J., Garcia, C.V., Lee, S.B., Shin, G.H., & Kim, J.T. (2019). Stability evaluation of turmeric extract nanoemulsion powder after application in milk as a food model. Journal of Food Engineering, 259: 12-20.

Pourbagher-Shahri, A.M., Farkhondeh, T., Ashrafizadeh, M., Talebi, M., & Samargahndian, S. (2021). Curcumin and cardiovascular diseases: Focus on cellular targets and cascades. Biomedicine and Pharmacotherapy, 136: 111214.

Prasad, R. & Shivay, Y.S. (2021). Scientific and medical research support can increase export earnings from turmeric (*Curcuma longa*). National Academy Science Letters, 1-3.

Prasad, S. & Aggarwal, B.B. (2011). Turmeric, the Golden Spice: From Traditional Medicine to Modern Medicine. In: Herbal Medicine: Biomolecular and Clinical Aspects. 2nd edition. (editors: Benzie, I.F.F.; Wachtel-Galor, S., Boca Raton (FL): CRC Press/Taylor & Francis. Chapter 13., pp. 263–288. Available from: https://www.ncbi.nlm.nih.gov/books/NBK92752/

Purnomo, D., Budiastuti, M.S., Sakya, A.T., & Cholid, M.I. (2018). The potential of turmeric (*Curcuma xanthorrhiza*) in agroforestry system based on silk tree (*Albizia chinensis*). In IOP Conference Series: Earth and Environmental Science (Vol. 142, No. 1, p. 012034). IOP Publishing.

Rahaman, M.M., Rakib, A., Mitra, S., Tareq, A.M., Emran, T.B., Shahid-Ud-Daula, A.F.M., Amin, M.N., & Simal-Gandara, J. (2021). The genus *Curcuma* and inflammation: overview of the pharmacological perspectives. Plants, 10: 63.

Rathaur, P., Raja, W., Ramteke, P.W., & John, S.A. (2012). Turmeric: The golden spice of life. International Journal of Pharmaceutical Sciences and Research, 3(7): 1987.

Ribeiro Oliveira, A., Chaves Ribeiro, A.E., Resende Oliveira, É., Oliveira Ribeiro, K., Costa Garcia, M., Careli-Gondim, Í., & Caliari, M. (2020). Physicochemical, microbiological and sensory characteristics of snacks developed from broken rice grains and turmeric powder. International Journal of Food Science & Technology, 55(7): 2719-2729.

Rivera-Mancía, S., Trujillo, J., & Chaverri, J.P. (2018). Utility of curcumin for the treatment of diabetes mellitus: Evidence from preclinical and clinical studies. Journal of Nutrition and Intermediary Metabolism, 14: 29-41.

Roh, S.M., Lawson, R., Lee, J.S., Suh, J. K., Criley, A.R. & Apavatjrut, P. (2006). Evaluation of *Curcuma* as potted plants and cut flowers. The Journal of Horticultural Science and Biotechnology, 81(1): 63-71.

Roth, G.A., Johnson, C., Abajobir, A., Abd-Allah, F., Abera, S.F., Abyu, G., ... & Ukwaja, K.N. (2017). Global, regional, and national burden of cardiovascular diseases for 10 causes, 1990 to 2015. Journal of the American College of Cardiology, 70(1): 1-25.

Roy, G.C., Chakraborty, K., Nandy, P., & Moitra, M.N. (2014). Pros and cons of curcumin as bioactive phyto-compound for effective management of insect pests. American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS), 7(1): 31-43.

Rubin, D.C., Shaker, A., & Levin, M.S. (2012). Chronic intestinal inflammation: inflammatory bowel disease and colitis-associated colon cancer. Frontiers in Immunology, 3: 107.

Sadeghian, M., Rahmani, S., Jamialahmadi, T., Johnston, T.P., & Sahebkar, A. (2021). The effect of oral curcumin supplementation on health-related quality of life: A systematic review and meta-analysis of randomized controlled trials. Journal of Affective Disorders, 278: 627-636.

Samson, S.L. & Garber, A.J. (2014). Metabolic syndrome. Endocrinology and Metabolism Clinics of North America, 43: 1-23.

Sharifi-Rad, J., El Rayess, Y., Abi Rizk, A., Sadaka, C., Zgheib, R., Zam, W., ... & Martins, N. (2020). Turmeric and its major compound curcumin on health: bioactive effects and safety profiles for food, pharmaceutical, biotechnological and medicinal applications. Frontiers in Pharmacology, 11.

Tang, C. H. (2019). Research of pathogenesis and novel therapeutics in arthritis. International Journal of Molecular Sciences, 20(7): 1646.

Tayyem, R.F., Heath, D.D., Al-Delaimy, W.K., & Rock, C.L. (2006). Curcumin content of turmeric and curry powders. Nutrition and Cancer, 55(2): 126-131.

ur Rehman, J., Jilani, G., Khan, M.A., Masih, R., & Kanvil, S. (2009). Repellent and oviposition deterrent effects of indigenous plant extracts to Peach Fruit Fly, Bactrocera zonata Saunders (Diptera: Tephritidae). Pakistan Journal of Zoology, 41(2): 101-106.

Velayudhan, K.C., Dikshit, N., & Nizar, M.A. (2012). Ethnobotany of turmeric (*Curcuma longa* L.). Indian Journal of Traditional Knowledge, 11(4): 607-614.

Wahanik, A.L., Neri-Numa, I.A., Pastore, G.M., Chang, Y.K., & Pedrosa Silva Clerici, M.T. (2018). Turmeric (*Curcuma longa* L.): New application as source of fiber and antioxidants in pasta with whole wheat flour. Revista Facultad Nacional de Agronomia Medellin, 71(1): 8423-8435.

Zaki Ahmad, M., Akhter, S., Mohsin, N., A Abdel-Wahab, B., Ahmad, J., Husain Warsi, M., ... & Jalees Ahmad, F. (2014). Transformation of curcumin from food additive to multifunctional medicine: nanotechnology bridging the gap. Current Drug Discovery Technologies, 11(3): 197-213.

Zou, L., Zheng, B., Zhang, R., Zhang, Z., Liu, W., Liu, C., ... & McClements, D.J. (2016). Enhancing the bioaccessibility of hydrophobic bioactive agents using mixed colloidal dispersions: Curcumin-loaded zein nanoparticles plus digestible lipid nanoparticles. Food Research International, 81: 74-82.

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