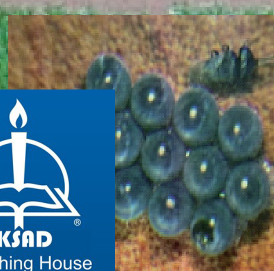



THEORETICAL AND PRACTICAL NEW APPROACHES IN CEREAL SCIENCE AND TECHNOLOGY



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CONTENTS

Cereals, the basic raw material of many food products in human nutrition, its importance continues to increase from the past to the present. However, the continuing increase in the world population and people's preference for quality products have made it necessary to increase the yield and quality of cereals.

This situation necessitated scientists to carry out new research to increase the yield and quality of cereals, and to take new measures to eliminate the factors that adversely affect the yield and quality of cereals. Stress factors that occur with climate change have made it necessary for researchers to find new measures. Especially biotic and abiotic stress factors cause significant yield losses in cereals. As in all studies, interdisciplinary studies are of great importance in studies on cereals. For this reason, scientists working in different fields related to cereals were brought together in our study.

The aim of this study is to present the readers with new approaches to increase the yield and quality of cereals, as well as modern methods for solving current problems. For this reason, I would like to express my special thanks to our esteemed authors who contributed to our work by sharing their research with us in the formation of our book.

Sincerely Yours

Mehmet KARAMAN

CHAPTER 1

WHEAT IMPORTANCE, HISTORY AND ADAPTATION

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INTRODUCTION

Wheat, a member of *Poaceae* family, is the ancient and the most cultivated of all cereals. It is produced aproximately on 215 million hectares in the world. It is generally accepted that wheat was the first grown crop about 10,000 to 8,000 BC. It is an importance source of calories (18%) and proteins (20%) for human since domestication with barley, peas, lentil, and chickpea in the Fertile Crescent, which includes the southern part of Turkey (Leonard and Martin, 1963; Kan et al., 2015; Muminjanov and Karagöz, 2018).

Turkey is one of the origin of genetic diversity of wheat (Leonard and Martin, 1963; Kan et al., 2015; Muminjanov and Karagöz, 2018; Harlan, 1995). Diploid wheat was firstly cultivated in the Karacadağ Mountains of Turkey and, then, spread to different regions of the world. Archaeological studies have revealed that wild wheats and species have taken an important place in the adaptation and the evolution of wheat (Leonard and Martin, 1963; Kan et al., 2015; Muminjanov and Karagöz, 2018). Wheat has also played an important role in the transition from a hunter-gatherer nomadic to a settled agriculture (Diamond, 1997).

According to the information obtained from the archaeological excavations, it is thought that agriculture in Anatolia had started about 10,000 years ago. The excavations carried out in Göbeklitepe (Şanlıurfa)-Turkey showed that, regular agriculture was practiced in that period as well as processing of wheat such as grinding (Bird, 1999).

The spread of wheat from its origin to the world has been through Anatolia and Greece (8,000 BP). It reached Balkan and crossed to Italy, France, and Spain (7,000 BP), finally the UK, and Scandanavia by about 5,000 BP. Moreover, wheat spread, via İran, into central Asia reaching China around 3,000 BP and to finally Africa via Egypt. It was introduced to Mexico in 1529 and to Australia in 1788 by Spaniards (Feldman, 2001).

Wheat characterized in two genera (*Aegilops* and *Triticum*) and three polidy levels (diploid 2n=14, tetraploid 2n=28 and hexaploid 2n=42) in Turkey (Table 1) (Muminjanov and Karagöz, 2018). *Triticum* species have been formed as result of natural hybridization between *Triticum* and *Aegilops.*

Table 1. Wheat Genetic Resources in Turkey

Ploidy	Taxon
Diploid (2n=14)	*Aegilops caudata, Ae. comosa* ssp. *comosa* and ssp. *heldreichii* *Ae. speltoides* var. *ligustica* and *var. speltoides, Ae. tauschii* *Ae. umbellulata, Ae. uniaristata* *Triticum boeticum, T.* ssp. monococcum *T. urartu*
Tetraploid (2n=28)	*Ae. biuncialis, Ae. columnaris* *Ae. cylindrica, Ae. geniculata* *Ae. kotschyi, Ae. neglecta* *Ae. peregrina, Ae. triuncialis* ssp. *persica,* and ssp. *triuncialis* *Ae. crassa* *T. carthlicum, T. dicoccoides* *T. dicoccon, T. durum, T. polonicum* *T. timopheevii, T. turgidum*
Hexaploid (2n=42)	*Ae. juvenalis, Ae. neglecta* *Ae. vavilovii* *T. aestivum*

The genus name '*Triticum*' was derived from Latin *tero* (I thresh). Three genomes (A, B (S), and D) have been part of modern wheat evolution. It has been reported that the donor of A genome is *T. urartu* (Dubbin et al., 1997) and B genome is *Ae. speltoides* (Gitte et al., 2006). There is an opinion that the donor of D genome is *Ae. tauschii* (Kimber and Feldman, 1987).

Triticum vulgare (no longer accepted) was being used instead of *Triticum aestivum* which defines the species name of bread wheat. Current name is *Triticum aestivum* refers to bread (or hexaploid) wheat. Bread wheat contains A, B, and D genoms.

The other main group of wheat is durum (or tetraploid) wheat (*Triticum turgidum* ssp. *durum*) that contains A and B genomes. This group is generally used for pasta production (Wrigley, 2009). Other minor wheat groups such as *T. monococcum* ssp. *monoccocum* and *T. timopheevii* are cultivated in small quantities on limited regions (Feldman and Sears, 1981).

Tetraploid *T. turgidum* (genomes AABB, 2n=28) was originated by the natural hybridization of *T. urartu* (A genome) and *Ae. speltoides* (B genome).

The diploid species are *T. urartu* (wild einkorn) and *Aegilops speltoides.* Diploid species have seven pairs chromosomes (2n=14). Origin of einkorn is Near East and cultivated einkorn probably originated in the mountains in southeastern Turkey.

Einkorn is probably the first cultivated wheat and it was distributed to other regions from Armenia, Georgia and Turkey where they are still produced and consumed. The cultivated wheat today has evolved from Einkorn with 14 chromosomes. 28 chromosomes wheat (tetraploid) was created from the crosses Einkorn with 14 chromosome wild grass. Wild emmer (T. dicoccoides) with 28 chromosomes can be found in nature. Emmer (T. dicoccum Schrank) with 28 chromosomes similar wild emmer was once widely cultivated (Anonymus, 2021).

Hexaploid *T. aestivum* (genomes AABBDD, 2n=42) was derived from the natural hybridization of *T. turgidum* ssp. *dicoccoides* (AABB) and *Ae. tauschii* (DD) (Feldman, 2001; Figure-1).

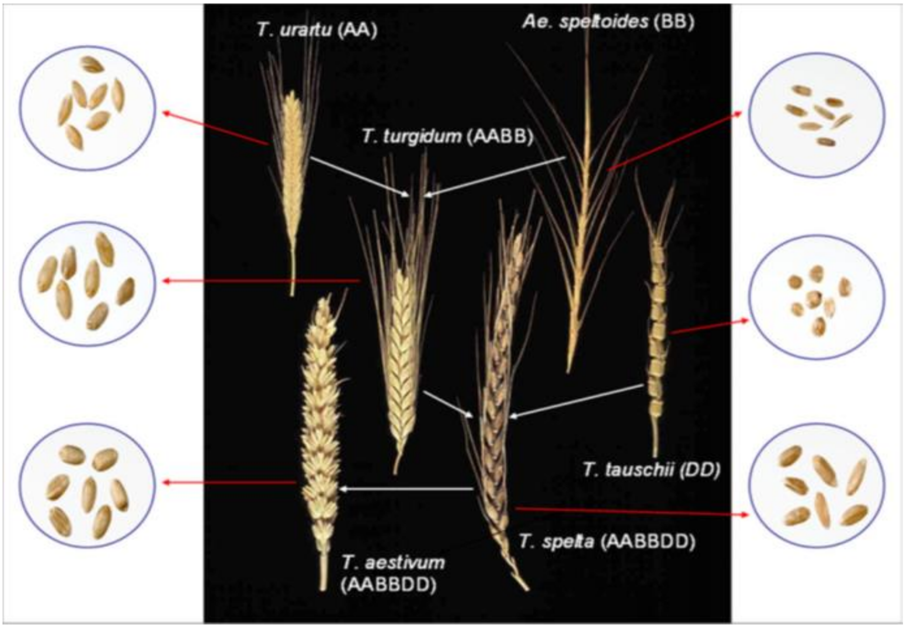

Figure 1. The evolutionary and genome relationships among cultivated bread and durum wheats and related wild diploid grasses, showing examples of spikes and grain. Modified from Snape and Pankova (2006).

Turkish wheat contributed the production in other countries as well. Many wheat cultivars, containing Turkish landraces in their pedigree, have been grown for resistance and tolerance against different rust and smuts in the United States (FAO, 1998).

ADAPTATION

Wheat is grown all over the world and also harvested during the year, its succes depends on its adaptability and high yield potential (Muminjanov and Karagöz, 2018).

According to data of 2019, world wheat cultivation was 214.7 million ha. Wheat production in the world was over 732 million tons. Major wheat producing countries are EU, China, India, Russia and USA. These countries realize more than 2/3 of the world wheat production. Turkey ranks in the top 10 countries in the world. China and USA have stocks more than half of their production. The third country with the most stocks is Russia. The yields of these countries are over 3 tons/ha (FAO, 2017; Atar, 2017; Anonymus 2020a).

Most of wheat regions in the world are between 25-40° S and 30-60° N in temperate regions. On the other hand, wheat also grows in the Arctic Circle and near the Equator. It is grown with fall plantings in dry subtropical climates where Mediterranean countries are located. Wheat is less important in warm humid regions because it is susceptible to disease (Leonard and Martin, 1963). The adaptation of wheat to wider environments are succeeded by genetic mechanisms which control the plant's response to day length (photoperiod) and temperature (Anderson and Garlinge, 2000).

The minimum temperature requirement of wheat is 3-4 °C, the optimum is about 25 °C and the maximum is 30-32 °C (Leonard and Martin, 1963). It is suitable for wheat 8-10 °C at the beginning of the development. Between tillering and stem elongation, 10-15 °C temperature and cloudy weather are suitable. Temperature and humidity demand increases after stem elongation. Days with high humidity and abundant light are suitable before heading. Bread wheat is more resistant to low temperatures than durum wheat (Gökgöl, 1939).

Flowering time in wheat is impressed by temperature. The development of some varieties does not continue unless the seeds or growing plants are sustained to a low temperature period. This is called 'vernaelization'. The temperatures required for vernaelization are between 1-10 °C. In varieties, vernalization necessity is not satisfied, the shoot apex vegetatively rests, only leaf primordia is formed. Winter wheat varieties reply better to vernalization (Anderson and Garlinge, 2000).

The susceptibility to decrease in daylength (photoperiod) change widely amongst wheat varieties. When a photoperiod sensitive variety is sustained to short day lengths, it replies by forming more leaf promoters on major stem before starting the ear.

Most sensitive wheat varieties to photoperiod respond to longdays throughout vegetative periods, as well as during productive period and stem elongation. The influence of longer days on plant growth differs among wheat varieties. While short exposure to long days starts the productive period in some not in, others (Anderson and Garlinge, 2000).

While the annual rainfall in wheat growing areas in the world is between 250-1,750 mm, it is 350-1,000 mm in the main wheat belt (Kün, 1988).

Wheat adapts well to medium-heavy texture and well-drained soils. High yield is obtained in silt and clay soils. Commonly, the yield is low in very sandy and poorly drained soils (Leonard and Martin, 1963). Increasied rate of humus in the soil also results in higher yield (Kün, 1988). Soils with a water holding capacity of 25-30% are suitable for wheat cultivation.

GREEN REVOLUTION

Industrial milling in the 1870s and genetic improvement in the 1950s and 1960s revolutionized yield and milling (Vergauwen and Smet, 2017).

Rapid population growth and poverty in the Asian continent after World War II caused food shortages (Perkins, 1997). The yield of wheat was very low. Already improved wheat varieties in that time were tall with a long straw, suitable for animal feding. It had lodging problem in sandy soil and windy condition. The problem was solved by the introduction of semidwarfing genes into wheat cultivars (Cracknell, 2016).

Especially in the 1960s, the biggest change in wheat is the significant height decrease. It has been probable to produce semi-dwarf wheats by adding a single Rht (reduced height) gene. These shorter wheats were more resistant to lodging and gave more yield. The reason for yield increase was the accumulation of photosynthesis in grains rather than leaves. The shorter height allowed farmers to farm larger fields with a mechanized one. It was dwarfing gene that doubled the wheat yield in the world in the 1960s and formed the basis of the Green Revolution (MacLean and Matthias, 2014).

In that year Dr. Norman Borlaug conducted some researches in Mexico. He is the most famous agricultural scientist in the modern world. Dr. Borlaug, the father of ‘Green Revolution’, is memorialized as the one who saved people from starvation in the 1960s and 70s. He developed a fertilizer-responsive variety of semi-dwarf wheat. Meanwhile, he discovered varieties with wide adaptability. These varieties could also be grown across continents (Baranski, 2015). Japanese scientist crossed Daruma Japanese landraces with Turkish red and improved high-yield ‘Norin 10’. Japanese dwarf wheat cultivar ‘Norin 10’was the source of short-strawed wheat (Cracknell, 2016).

Dr. Borlaug discovered that wide adapted-stable wheat varieties increased wheat yields worldwide. These have been the primary cause in the 'Green Revolution’. Because of Green Revolution cereal production increased by over 250% in some countries. Production increases attributed to get rid of hunger. Green Revolution has diminished food security in many non-industrial nations (Cracknell, 2016). Dr. Borlaug was awarded by Nobel Prize in 1970 because of his work (Vergauwen and Smet, 2017).

WHEAT IN TURKEY

Turkey is known as one of origin center of wheat and wild wheat species. These species have played an important role in the evolution and adaptation of bread wheat. Southeastern Anatolia is a region where wheat was first cultivated and wild ancestors of wheat naturally spread from (Nesbit and Samuel, 1996).

Wheat farming in Turkey has been done for many years, however, modern varieties have been produced since early 1900s. Semi-dwarf highly adapted varieties received from Mexico in 1966. Yield increased not only by using new wheat varieties but also by some more inputs (pesticides and fertilizer) (Kan et al., 2015).

Wheat production area was less than 3 million ha at the beginning of 20th century in Anatolia. Yield potential of wheat landraces was around 1.7 t/ha under low input conditions during years even with good climatic conditions. Wheat yield dramatically decreased after 1914 till 1930's mainly because of poor agricultural practices caused by lack of manpower due to wars (Anonymus, 2006; Anonymus, 2009).

Wheat breeding activities began in 1925 after the establishment of the Republic of Turkey. Since 1925, many modern varieties have been improved from local population and from some introduced material (Altıntaş et al., 2008).

Introduction of mechanization increased the area sown to wheat production from 4.5 million ha in 1950 to 7.7 million ha in 1960. However the average yield did not increase dramatically in the same period, because the improved varieties have not been introduced on a large scale. Then Turkey started to test high yielding varieties (HYV) of CIMMYT – Mexico in 1964. The first area to replace the local varieties with so called “Mexican wheat” was the Meditterranean coasts in 1967. Mexican cultivars covered around 60% of the coastal spring wheat area by cultivar Penjamo 62. The other Mexican cultivars were not widely grown due to susceptibility to yellow rust (*Septoria tritici*) (Braun et al., 2001).

Turkey's farming land area is 29.5% (23.09 million hectares) 66.6% (15.4 million hectares) of our agricultural lands, excluding fallow lands, are reserved for field agriculture. Cereals are cultivated in approximately 70% of this area (10.77 million hectares). Wheat ranks the first with a share of 64%, barley the second with a share of 27%, and maize the third with a share of 5.9%. These products, respectively; followed by rice, rye, oats and triticale (Anonymus, 2020b).

Wheat production is carried out in every region of our country. In the last 20 years, wheat cultivation areas have varied between 6.8-9.4 million hectares and its production between 17.2-22.6 million tons. Our wheat consumption is around 19.0-19.5 million tons (Anonymus, 2020b).

Turkey is appropriate for wheat cultivation because of environmental conditions. Three out of four farmer grow wheat in Turkey. Wheat is commonly produced as spring type in Aegean, Mediterranean, Marmara coastal and, winter-facultative in other regions (Kan et al., 2015). The mean yield of wheat is 2,781 kg/ha in Turkey in 2019 (Anonymus, 2020b), but yield varies between regions and wheat types.

Gökgöl (1939) notes that Turkey's wheats have high potential for superior industrial quality. Based on the various desired quality characteristics people developed several local products. Turkish citizens are one of the highest wheat consumers in the world. Annual wheat consumption is around 200 kg/capita. Wheat is consumed in several forms of bread such as soft bread, flat bread (pide), thin bread (yufka), pasta (both home made and commercial), cracked wheat (bulgur), and semolina. It is common to consume sesame seed coated of bread with cheese and tea (Morgounov et al., 2016).

WHEAT LANDRACES

When the seed of a variety is planted in one region for at least one farmer generation, it is defined as a local variety (Louette, 2000). Harlan (1992) describes the landraces as "balanced populations – variable in equilibrium with both environment and pathogens and genetically dynamic".

Although modern varieties are grown extensively in wheat agriculture, the rate of landraces is 1%. This outcome indicated that there has been a decrease in genetic diversity of wheat. Landraces are named and kept up by farmers to meet their social, financial, and ecological requirements, and are produced for home consumption and small marketing (Kan et al., 2015; Karaman, 2020).

Many modern wheat cultivars are usually genetically similar, with a rather narrow genetic base. Effect of green revolution is significant in narrowing the genetic base of wheat landraces in Turkey (Zencirci and Baran, 1992). Therefore, new genetic diversity is needed. Landraces appeared through a combination of natural and farmers selection have consisted of a large genetic diversity and, therefore, can supply precious feature for plant breeding. Local varieties are known tolerant of biotic and abiotic stress factors and their good yields. Landraces can be regarded as a precious piece of the gene pool (Keller et al., 1991).

Extinction of genetic resources and genetic erosion are a big problem in Turkey. Modern but less adapted varieties which are less resistant to diseases and pests are replacing landraces (Kan et al., 2015).

The cultivation of landraces is constantly decreasing compared to the past. As a matter of fact, when the results of a study conducted by Morgounov and his team in 2016 were compared with the study conducted by Mirza Gökgöl in 1920, it was observed that the genetic diversity in wheat was lost by 50% to 70%. As a result of the research carried out by Morgounov et al. (2016) the names of the landraces have changed over time, while 40% of the landraces in the past spring, more than 95% of the landraces today are winter, 41.5% of the village varieties grown in the past are durum, 39.9% bread wheat and 14.2%

club wheat. While these rates belong to club wheat species/ subspecies, it has been determined that these ratios are 52.9% bread wheat, 38.2% durum wheat and 2.2% club wheat, respectively (Morgounov et al., 2016).

CIMMYT notified that Turkey's modern varieties grown only 31% of wheat are in 1990 (Brush and Meng, 1998). Currently there is no official record of wheat land races areas. It is estimated that landraces are cultivated in about 800,000 ha in Turkey. However, landraces are being replaced by modern varieties, and continue to disappear irreversibly. Landraces can be protected by preserving traditional information, recording them, establishing a market and proposing themselves for organic agriculture (Karagöz, 2014).

Diversity is an important not only for potentially useful traits, but also because of its ecological services to farmers, such as the ability to exploit heterogeneous or marginal environments or partake as a buffer against the diseases. A decline in diversity among crops will lead to instability because of vulnerability to pests and susceptibility to the moods of climate fluctuations (Brush, 2004).

The consumption of einkorn and emmer have been substituted by modern attractive and cheaper modern varieties. Their market are limited with no, no trading organization. Their milling is difficult process, too.

In the early 20th century Turkish scientist Mirza Gökgöl collected wheat landraces from around Turkey and revealed their properties. He is known as the pioneering collector of wheat genetic resources for wheat improvement in Turkey. He characterized 36,000 accession, described 18,000 wheat type containing 256 new varieties.

Gökgöl found that nearly all wheat diversity available in the world were already in Turkey (Gökgöl, 1935). Gökgöl stated that “wheat landraces provide an infinite wealth for plant breeders in Turkey” (Gökgöl, 1939).

Gökgöl’s work is published in two book volumes 'Wheat for Turkey' (Gökgöl, 1935; Gökgöl, 1939). These books provided important information about wheat cultivation before industrialization in agriculture. They containe basic information about local varieties grown before modern ones (Morgounov et al., 2016).

The diversity of cultivated and naturally grown plants has attracted the attention of many scientists. Vavilov, Zhukovsky, and Harlan are important researchers who worked on Turkish wheat. Zhukovsky collected about 10,000 cereals, vegetables, and forage crops during 1925-1927 (Zhukovsky, 1951).

Harlan made a collection that consisting of 2121 wheat (*Triticum monococcum*) and wild relatives between 1948 to 1949. These populations were examined for their botanical and agronomic properties (Harlan, 1950). He surveyed Turkey again in 1964. Later in 1993, Harlan was once again in Turkey for the preparatory phase of GEF funded “In situ conservation of genetic diversity project”.

Collecting efforts have not been limited to Gökgöl. Harlan mentioned names of several Turkish scientists accompanied him during the mission in 1964. Among them are Osman Tosun of Ankara University and some of his students and colleagues. After the establishment of plant genetic resources research system, project based systematic collecting missions were organized to several parts of Turkey (Harlan, 1995). The studies carried out by these three researchers mentioned above have shed great light on Turkish scientists.

Turkey's genetic resources promoted to the improvement of wheat production in the world. German Mennonites migrated into the Crimea and from there in 1873 to Kansas, carried seeds of landrace variety Turkey Red. This landrace served as the ancestral foundation for the hard-red winter wheat gene pool in North America (Braun et al., 2001).

Wheat landraces are generally conserved in the form of the population in Turkey. Therefore, these landraces have genetic and phenotypic variation (Brush 2004).

Turkish germplasm is kept in several international research centers and national gene bank as well. Brush (1998) reports there are 5,852 tetraploid and hexaploid Turkish accessions among various international collections. Today some 50,000 materials representing over 600 genera are kept in Turkey's National Gene Bank. Of those material about 10,000 accessions belong to 2,400 wild species (Anonymus, 2008).

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CHAPTER 2

HEAT STRESS ADAPTATION IN WHEAT THROUGH PHENOTYPING

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INTRODUCTION

The effect and intensity of the heat stress, which leads to substantial losses in food production, is expected to be increased by global climate change (Talukder et al., 2014). Wheat is a major grain commodity that accounts for 30% of world grain output and satisfies 36% of the world population's dietary requirements (Cossani and Reynolds, 2012; Prerna and Sengar, 2013). An average worldwide temperature increase of 0.3% per 10 years is expected to lead to a 50% yield decline in South Asia by 2050 (IFPRI, 2009). The World wheat yield has declined 5% as a result of the global temperature increase since the 1980's (Lobell et al., 2011). The yield was found to decline by 3-4%, each grade rising above the optimum daytime temperature (15-20°C) of wheat (Wardlaw et al., 1994). High temperature stress negatively affects some physiological and biochemical events depending on the senescence process of leaves, directly or indirectly affects many events such as the decrease of the crop assimilation area, loss of photosynthetic rate and pigment, which is caused to large decline in the stomatal conductance (Farooq et al., 2011; Kobata et al., 2012; Rezaei et al. 2015). These effects adversely affect grain filling rate and duration and grain weight. It is estimated from long-term climate projections that wheat will maintain its importance in the future and despite intensive breeding efforts, the increase in yield will not keep up with the population growth expected to be 9 billion in 2050 (Stamm et al. 2011). Drought and high temperature stress are the two most important factors that restrict current global wheat production and the improvement in yield in conditions with low yield potential. In addition, wheat production areas, which currently have high yield potential, are expected to turn into stressfully conditions in the future due to global climate change (Ortiz et al. 2008; Lopes et al. 2012).

Although Fisher (2007) noted that a discontinuance of genetic gain in Mexico, the hometown of the green revolution, between 1996 and 2005, annual increases in spring wheat yields of up to 1.9% were observed under abundant nitrogen and wet conditions (Ortiz et al., 1997). Wheat's average annual genetic gain has been estimated to be 1% (Dixon et al., 2009), while demand for wheat is increasing at a rate of 1.7% per year, reaching a total of 1 billion tons in 2050 (Rosegrant and Agcaoili, 2010).

Until recently, yield was used as a breeding criterion in wheat breeding studies. However, since the yield varies greatly depending on the environmental conditions, success in breeding has not been very high, especially in the stressful conditions. Better understanding of the physiological reasons limiting yield has created new opportunities in recent years. For this reason, it is now adopted that the next success can be achieved by using yield-related characteristics, especially physiological characteristics, as a supportive criterion. For this reason, it is now adopted that the next success can be achieved by using yield-related characteristics, especially physiological characteristics, as a supportive criterion (Araus *et al*., 2003; Koç et al., 2008). The most important conclusion reached from these studies is that the first step in performing studies on agro-ecological conditions is to determine which traits or features can be applied successfully for that agro-ecological condition. Another notable result is that the characteristics such as light reflections and $\Delta^{13}C$, which are based on instantaneous measurements and are more stable than the leaf physiological characteristics, which can vary greatly, demonstrate total activity of vegetation and seasonal activity.

The climatic conditions that are already unfavorable for wheat in many parts of the world have become more and more unfavorable with the global climate change we have entered into. Therefore, in order to cope with hot and dry conditions without wasting any more time, both cultivation techniques should be adjusted and durable wheat varieties should be developed. The first step in this way is the selection of supportive physiological breeding criteria that can accelerate traditional breeding efforts. The support of physiological criteria is of greater importance in stressful conditions where success in breeding is lower than favorable conditions due to stress. Nowadays, it is reported that the integration of physiological criteria into breeding programs that can accelerate traditional breeding studies in international breeding organizations such as CIMMYT has become almost routine (Reynolds et al., 2012).

Despite the realization of the importance of the subject in developing countries, it has been disregarded due to the insufficient technical and scientific infrastructure and the laborious and expensive physiological measurements. However, with the development of very inexpensive devices that can make quick and practical measurements in recent years, "the chance of easier and cheaper breeding" has now arisen (Reynolds et al., 2012). In order to be successful, each feature that can be considered as supportive should first be determined in relation to yield in the relevant agro-ecological conditions. In recent years, features such as cooling, radiation reflections and, in particular, Carbon-13 discrimination ($\Delta^{13}C$) have been highlighting among the physiologic characteristics that may be used as breeding criteria. They show complete vegetation activity and seasonal activities.

1. Heat stress and Wheat

Even though wheat, a C_3 and cool climate plant, is generally thought to be resistant to stressful conditions, it is actually a cultivar plant and because of this, it cannot handle water wastefully (produces a limited amount of biomass or yields in return for the water it uses) and is more susceptible to hot temperatures. The temperatures at which the wheat plant can and cannot grow, varies with its development period. According to the report of Porter and Gawith (1999), temperature that adversely affect the development process of wheat; 22.0 (± 1.6) ºC during germination and emergence, 10.6 (± 1.3) ºC during spike formation, 21.0 (± 1.7) ºC during flowering and 20.7 (± 1.6) ºC during grain growth, and the temperatures at which the growth started to stop were 32.7 (±0.9)ºC, 20.0ºC, 31.0ºC and 35.4.0 (±2.0)ºC, respectively.

High-temperature stress is particularly observed during the grain filling period in spring wheats in the Mediterranean climate zone and may sometimes affect flowering. The stress seen during the grain filling period is called terminal temperature stress (Rehman et al., 2021). High temperature have been shown to have a significant impact on the grain filling rate of wheat (Slafer ve Satorre, 1999: Viswanathan and Khanna-Chopra, 2001). While high temperature have the good effect of increasing grain growth rate, they also shorten the grain filling duration and reduce overall yield (Tahir and Nakata, 2005). This demonstrates that the rate of grain filling is very sensitive to changes in temperature. In this period, the grain filling duration is shortened by the effect of high temperature and the grain weight decreases as the photosynthesis process is negatively affected (Hays et al. 2007; Barnab'as et al. 2008). For example, heat stress shortened grain filling time by 10 days in wheat under field conditions (Koc et al. 2008). When plants are subjected to terminal stress, the increase in total degree-day (temperature sum) due to high temperature and generally high light energy accelerates ripening and causes a shorter grain filling duration. In such cases, genotypes with a high grain filling rate have an advantage. Similarly, the spread of heat stress throughout the plant's development period has a negative impact on leaf and spike development, the number of spikes, the number of grains per spike, and the number and weight of harvestable grains, resulting in a reduction in yield potential (Butterfield and Marison 1992). The impact of temperatures above optimal can be seen as decreases in growth rates, in particular decreases in development time and the senescence accelerations due to the increase in respiration (especially at night, photorespiration at day). The adverse effect of high temperatures is known to be valid for the entire plant life, depending on the grade and duration of the temperature, from germination to maturity (Blum, 1988). It is well known that the negative effect of temperature, which rises gradually in the late stages of growth, expresses itself through flower number and fertility, grain formation and filling in parallel with the natural seasonal temperature phase (Ugarte et al., 2007). Fischer (1985) established a negative relationship between grain number and temperature during spike growth and flower development, as well as demonstrating that the photo-thermal coefficient (solar radiation / average temperature) of the one-month prior to flowering, during which the grain number was determined, was highly correlated with grain yield. In the majority of wheat producing regions, terminal heat stress during grain filling is more detrimental than pre-flowering heat stress (Kumar et al., 2012). High temperature during grain filling have been shown to accelerate grain growth and shorten grain filling time and when this shortening cannot be compensated for by increasing grain filling rate, yield decreases as a result of the grain weight decrease (Gibson and Paulsen, 1999).

As well as having a direct impact on grain growth, high temperature can also have an indirect impact by speeding up the aging of the plant's leaves. As well as having a direct impact on grain growth, high temperature can also have an indirect impact by speeding up the aging of the plant's leaves. High temperature cause rapid yellowing of wheat leaves by activating metabolic pathways that accelerate the aging process (Paulsen, 1994). According to Zhao et al. (2007), a large range of daily temperature changes has an accelerated impact on the senescence of the leaves (Chlorophyll loss), and the stay green duration of the leaves of the genotypes after flowering is important in the growth of the grains.

Recent studies have shown that short-term high temperatures also cause losses in the yield and quality of wheat. In addition, it is known that short-term sudden temperature increases in special periods of development such as flowering and grain set are critical in terms of causing irreversible losses in the number of grain due to flower infertility (Ferris et al., 1998; Djanaguiraman et al. 2020). In the Mediterranean and WANA conditions, it has been shown that high temperatures are a problem during germination-emergence and initial growth, as well as stress in the late periods (Wollenweber et al., 2003; Cheabu et al., 2018).

High temperature generally has a detrimental effect on development by shortening the time required for growth. The calculations made based on the studies carried out in tunnel greenhouses where gradual temperature increase is applied, showed that 1 degree increase in temperature can cause 8% decrease in development time and 6% decrease in grain filling time (Reddy and Hodges, 2000). In order to determine the effect of temperature on wheat, the study carried out in normal and late sowing periods under rain-fed and irrigated conditions showed that an increase of 1°C in temperature causes an average of 8% decrease in flowering time (Koç et al., 2004). The yield losses in this study varied between 5.5% and 18% in irrigated conditions and between 28% and 41% in dry conditions. In the Mediterranean climate conditions, it is observed that wheat has entered the most sensitive development period in the spring months, when temperatures rise rapidly and rainfall amount and Frequency begins to decrease. In this climate, the high temperature, which starts approximately 3-4 weeks before flowering and progresses to maturity, is an important stress factor limiting the yield in wheat (Koç et al., 2008a; Barutcular et al., 2016).

2. Target Traits

Before going into the temperature-related properties, a few basic formulas that show the general principles of yield formation in wheat are briefly emphasized in order to clarify the mechanism of effect of the feature to be discussed on yield under heat stress.

Grain yield: Grain number x Grain weight (General yield model)

Grain yield: LI x RUE x HI (Heat stress model)

Grain yield: WU x WUE x HI (Drought stress model)

Where: HI = harvest index; LI = light interception; RUE = radiation use efficiency; WU = water uptake; and, WUE = water use efficiency, adapted from Reynolds et al., 2007.

These yield models give a generalized conceptual model of a core set of wheat features for adaptation to both dry and hot irrigated conditions. When looking at group characteristics it is obvious that under more than one setting, a number of physiological systems are likely to benefit. A rapid ground cover is a valuable feature, for instance, in the pre-anthesis drought stress (Loss and Siddique,1994) in order to minimize waste of soil waters, fast growing early in heat enhances interception and therefore reduces tillering loss in crop absorption (Rawson, 1986).

Plant physiologists have often failed to determine the relationship between yield and leaf activity, particularly to increase photosynthetic activity (Evans, 1993). Genetic variation in temperature response was found among wheat varieties exposed to high temperature under controlled conditions (Blum, 1986) and the variation in photosynthesis under temperature stress was associated with the change in chlorophyll-a / b ratio and chlorophyll loss due to early senescence of the leaf (Al-Khatib and Paulsen, 1984; Harding et al., 1990).

In addition, studies conducted in CIMMYT (International Maize and Wheat Improvement Center located in Central Mexico) show that there is genetic variability in terms of photosynthesis rate in temperature stress under field conditions (Delgado et al., 1994). Reynolds et al. (1994) stated that under heat stress conditions, canopy temperature depression (CTD) and stomatal conductance (g_s) are associated with the rate of photosynthesis as well as grain yield in field conditions. CTD is utilized extensively by CIMMYT and practically employed in dry and hot environments in plant selection. g_s has been a subject of study in terms of its relation to drought tolerance or yield potential in plants (Fig 1). In the late 1980s, CIMMYT initiated air temperature and CTD measurements in various trials irrigated in Northwest Mexico, and it was mostly revealed that the relationships between grain yield and CTD were positive (Bahar et al., 2009). There are positive relationships between grain yield, photosynthesis rate and stomatal conductivity (g_s) in irrigated short spring wheat. New evidence supporting grain yield-g_s relationships has also been obtained from Carbon-13 discrimination ($\Delta^{13}C$) studies (Condon et al., 1990). In order to be successful, each feature that can be considered as supportive should first be determined in relation to yield in the relevant agro-ecological conditions (Karaman et al., 2014). One of the most important indicators of the plants' tolerance to heat stress is the cooling ability they obtain with the transpiration caused by the activity of stomatal conductance. Daily and seasonal variations affect stomatal conductivity, making precise measurement difficult. Stomatal conductance can change rapidly in response to factors such as photosynthetic active radiation and temperature, in a short-term and intermittent manner (Squire and Black, 1981). Stomatal conductance varies with the plant-water potential due to seasonal and daily changes as well as genotypic effect. In order to reveal genotypic differences in terms of transpiration, evaluations should be made in environments where water is not a limiting factor (Condon and Richhards , 1993).

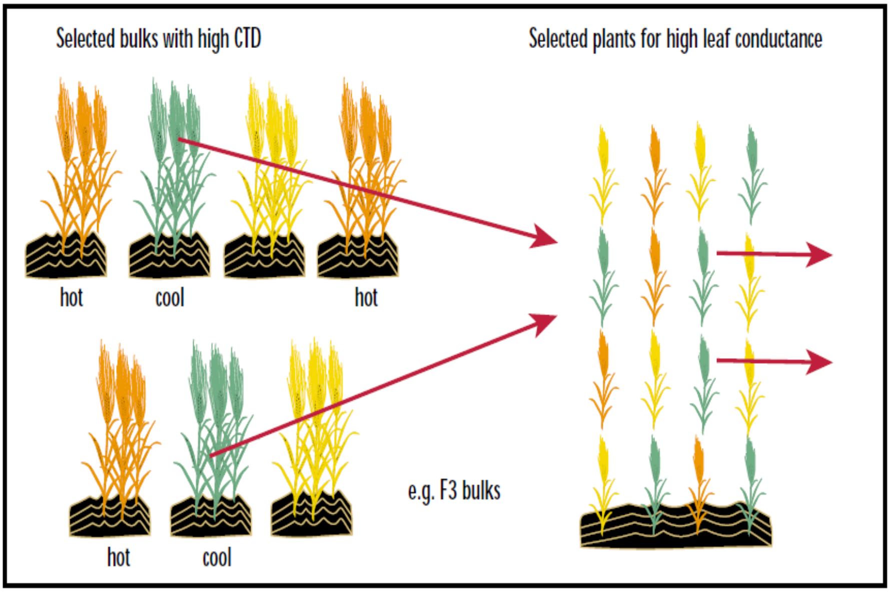

Figure 1. This graphical representation shows how CTD and leaf conductance have been utilized in the early generations of wheat (Reynolds et al., 2001)

One of the devices that determines stomatal conductance quickly, but indirectly, is the infrared thermometer used to detect plant canopy temperature decrease in response to air temperature named canopy temperature depression (CTD). The value obtained from this device is equal to the difference between the air temperature and the temperature of the plant community, and it is higher in well-irrigated wheat. CTD variations in different periods of bread and durum wheat genotypes are shown in Figure 2 and 3 respectively. Researchers stated that CTD increases with the increase in g_s when other variables are constant in the measurement made with infrared thermometer in irrigated wheat (Pinter et al., 1990). It has also been stated that the vapor pressure deficit (VPD) has a significant effect on CTD (Medina et al., 2019). CTD should be measured under conditions where the air is hot, the relative humidity is low and therefore the water vapor deficit is high, because it is affected by biological and environmental factors such as soil water condition, wind, evapotranspiration, cloudiness, conduction system, plant metabolism, air temperature, relative humidity and continuous radiation (Reynolds et al., 2001). CTD and g_s are used as selection criteria in wheat breeding, and it is generally applied by mass selection method in the early generation such as the F3 stage. According to this method, bulks with high CTD in the F3 generation, in other words with a cool plant population, are selected; Then, single plants with high stomatal conductivity are selected among the determined bulk and thus both properties are used together in the breeding program (Reynolds et al., 2001).

The negative effect of high temperatures, depending on the degree and duration of the temperature, may occur throughout the life of the plant from germination to maturity (Blum, 1988). Different metabolic processes may play a role in tolerance to high temperatures. In varieties that adapt to high temperatures, the ability of cell membrane systems to continue to function at high temperatures is seen as one of the most fundamental elements of the adaptation mechanism (Dhanda and Munjal, 2009). In addition to the measurement of leaf chlorophyll fluorescence (reflectance ratio of absorbed light) in the determination of high temperature damage, another current method, which is widely used, is the membrane (cell membrane) thermostability (MTS) test.

There are various mechanisms of resistance to high temperature in cereals. Membranes are physiologically damaged in the first degree by temperature and the damage level of the membranes can be estimated by measuring the substances leaking from the tissues. MTS with high heritability shows high genetic correlation with yield (Yildirim et al., 2009). The use of this potential in breeding requires laboratory work and measurements. The best way to minimize the negative impact of high temperatures is to develop tolerant varieties. Membrane stability and fluorescence in the leaf are the most important breeding criteria that have been emphasized in recent years in the selection of varieties that can tolerate high temperatures.

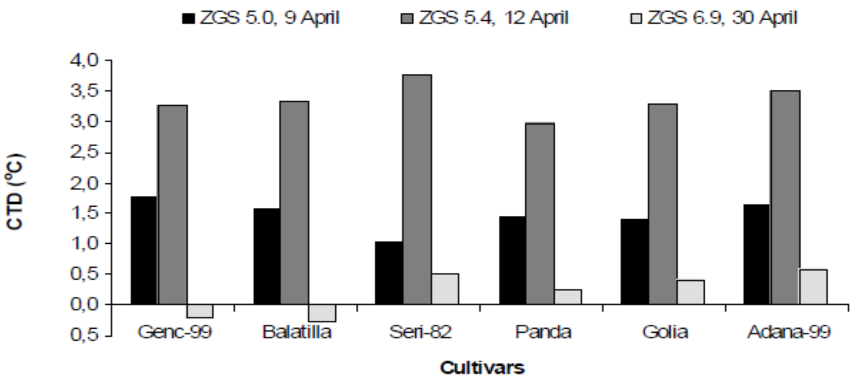

Figure 2. CTD (Canopy Temperature Depression) values of bread wheat genotypes (Bahar et al., 2008)

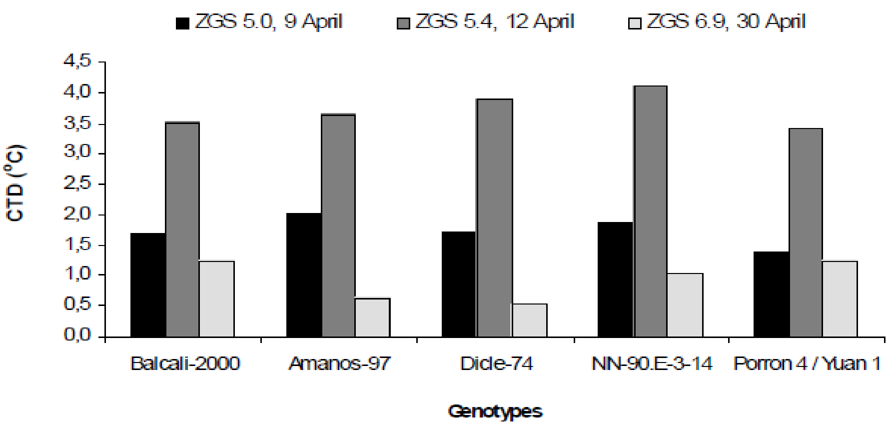

Figure 3. CTD (Canopy Temperature Depression) values of durum wheat genotypes (Bahar et al., 2008)

2.1. Agronomic Traits

Grain yield in wheat is a very complicated feature that is the product of various processes that occur at all levels of plant development, from the molecule to the population. The majority of molecular, biochemical, and even plant-level properties addressed in the literature are unrelated to yield and stability under field settings, or are only slightly connected (Araus et al., 2001). In order to have successful breeding, characteristics should be linked to yield and stability in the field. Many of the traits that positively affect yield under stress are complex traits controlled by multiple genes (Rebetzke et al., 2007; Rebetzke et al., 2008; Yang et al., 2007). In environments with high heat stress (HS), grain production was inversely linked to spike weight, harvest index, grain numbers per plant, and biological yield (Yıldırım and Bahar, 2010). Additionally, a characteristic that is critical to one environment may be irrelevant to another.

The green revolution increased yields in current wheat types by lowering the plant height and offering high harvest index (HI) and lodging tolerance, while maintaining a relatively constant biological yield. Increases in harvest index occurred as a result of grain number increases (Sayre et al., 1997; Fisher, 2007), rather than grain weight increases found under certain conditions (Richards et al., 2002). In other words, improvement in breeding has been achieved by developing varieties that produce a large number of grains and are capable of filling them. Increased grain number is highlighted as another important factor in arid and hot environments. In both favorable and stressful conditions, it has been discovered that the number of spikelets and, more specifically, the number of florets that can develop into grains within each spikelet are positively associated to yield (Barutçular et al., 2006; Koç et al., 2008a). In order to achieve the goal, an architectural structure should be designed to direct resources to the growth of existing spikes, after providing strong emergence in the plant, covering the soil surface early and then limiting the formation of late tillers during periods of abundant rainfall and cool weather. Adaptation to stressful conditions also depends on whether critical developmental periods match with stressful conditions. Appropriate flowering period is the most important adaptation feature in adaptation to favorable and stressful conditions. Stress factor in wheat shows that, its effect in different ways according to the period of phenological development. Heat stress that occurs before the flowering period causes a decrease in the number of ears per unit area, the number of fertile spikelets per spike and the number of grains per spike (Shpiler and Blum, 1991; Ishag and Mohamed, 1996). In addition, harvest index and grain number were also shown to be significantly correlated with yield during terminal heat stress (Tekdal et al., 2017). The feature of early ground cover increases the light absorption and transpiration efficiency while minimizing yield losses (Ludlow and Muchow, 1990), and there is genetic variation in cereals for this feature (Regan et al., 1992). High temperatures cause significant negativities not only in grain weight but also in grain number (Wardlaw et al., 1989).

2.2. Morphological Traits

Traits such as the color of the leaf and its waxy structure affect the energy (light) and water losses in the leaf. Since the waxy leaf reflects the light more, the leaf surface becomes cooler. Since it is cool, transpiration on the leaves is also less. Transpiration is also less at night. Leaf rolling is an adaptation mechanism that delays leaf aging by temporarily by passing water loss and excessive energy load in dry and hot weather. However, long-term leaf rolling is a feature that can negatively affect plant development and dry matter accumulation. It was stated by Richards (2001) that leaf rolling during the flowering period can cause problems.

Coleoptile length and seedling emergence varies for various wheat varieties under heat stress (Burleigh et al, 1964). At irrigated conditions, the Heat Stress Index and coleoptile length were shown to be significantly correlated (Toptaş et al., 2016a).

2.3. Physiological Traits

Heat stress in general negatively affects all physiological and other metabolic processes in wheat. The photosynthesis and chlorophyll content decreases under hot conditions (Reynolds et al., 1994). Photosynthesis in plants is carried out by many enzymatic reactions, and there are interrelated mechanisms such as electron transport systems and light capture systems, where ATP production takes place. Stress damage to any of these systems has a negative impact on the entire photosynthetic process (Allakhverdiev et al., 2008). Properties such as chlorophyll content, net assimilation rate, transpiration amount and rate, stomatal conductance and intercellular CO_2 concentration, which are related to the photosynthesis mechanism, also decrease in relation to drought under heat stress. Properties related to the photosynthesis mechanism, such as chlorophyll content, net assimilation rate, transpiration amount and rate, stomatal conductivity, and CO_2 concentration between mesophyll cells, decrease in relation to drought under heat stress. For this reason, physiological parameters and yield factors should be considered together in determining the heat tolerance in wheat.

When heat stress occurs, physiological properties such as cooling ability, membrane thermostability, leaf chlorophyll content at grain filling period, stomatal conductivity and photosynthesis rate at heading time were positively correlated with biological yield, number of grains per unit area, number of grains per spike, anthesis time, physiological maturity time, ground cover rate (post germination) and grain yield (Reynolds et al., 2001). In studies carried out in field conditions in bread wheat, it was found that varieties with high harvest index, grain number per spike, flag leaf gas exchange rate (net photosynthesis rate, transpiration rate and stomatal conductivity) and high flag leaf ash content were temperature tolerant, while cultivars with large and wide flag leaf were temperature sensitive. (Koç et al., 2008). CTD and high grain filling rate were found to be associated with heat tolerance in durum wheat (Tekdal and Yıldırım, 2017). Therefore, the importance of physiological characteristics related to efficiency in hot environments has been revealed by many studies (Table 1). Uptake of CO_2 by photosynthesis (assimilation of carbon dioxide) and loss of water by transpiration (evaporation of water) are two important interrelated processes, both of which depend on stomatal conductivity. It is noted that, as measured by net photosynthetic rate and stomatal conductivity, there is a positive association between yield in spring wheat, and this link is further evidenced in the experiments done at CIMMYT in the 1990s. These two features, which have a strong positive correlation with increases in yield potential in Mexican conditions (Rees et al., 1993; Fisher et al., 1998), are also associated with the genotypes' performance under high temperature (Reynolds et al., 1994, Reynolds et al., 2000). Because, biological efficiency does not always improve in lockstep with photosynthesis rate, a disagreement has erupted over which of these two processes (net photosynthesis rate or stomatal conductivity) is "more essential" in stress adaptation. Under heat stress conditions induced by late planting, gas exchange parameters decreased (Figure 4) .Richards (1996b) states that the primary impetus is the high grain number, which simultaneously results in a rise in photosynthesis and photosynthesis demand in order to meet the assimilate need, which increases with the grain number. This demonstrates that regardless of the rationale, it can be deduced that those genotypes which can take up more water from the soil, maintain their water status throughout development, and are equipped with actively growing leaves will have a competitive advantage. In studies of the relationship between grain production and heat tolerance, increasing leaf photosynthetic rate and stomatal conductivity were found to be connected to increased yield and increased heat tolerance (Koç et al., 2008a). Preparation of the experiment in the measurement of these features must first be determined, because measurement of these features can be difficult and are affected by internal and environmental factors. It is then necessary to figure out when, how, under what conditions, and how much measurement will be performed beforehand in order to lower the variation.

The rate of absorption of CO_2 is highly affected by high temperatures (Law and Craft s-Brandner, 1999). Improves on the stomatal conductance of heat treated plants have been reported, showing that

CO2 decrease due to high temperatures is produced. The gas exchange was successfully utilized to wheat to detect heat tolerances of cultivars or advanced lines (Reynolds et al., 2000).While, water loss through the leaves other than the stomata (epidermal, residual, or cuticular transpiration) is typically less than10%, it can account for up to 50% of total water loss in dry conditions and up to 100% at night (Sabour et al., 1997). Richards (2001) stressed that the water loss-causing aspects other than stomata, as it causes water to be lost, are more significant in settings where the VPD is quite severe at night.

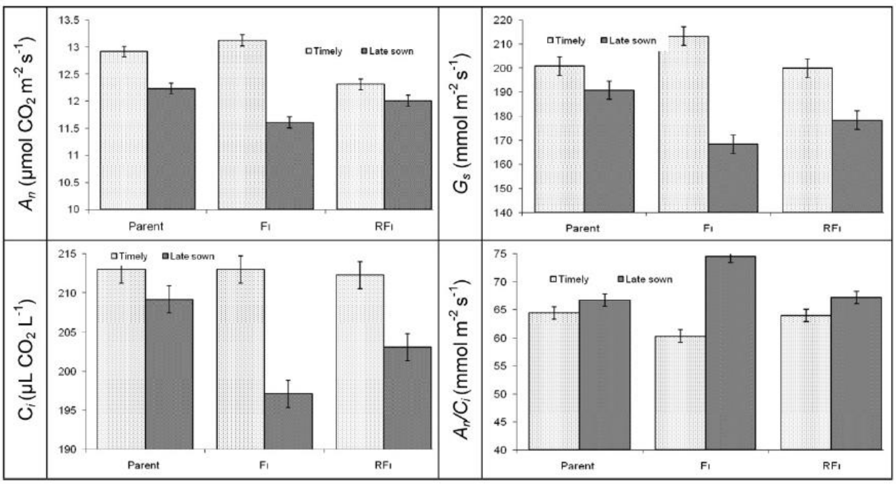

Figure 4. Gas exchange changes under heat stress generated by late sowing in wheat F_1 crosses (Yildirim et al., 2013)

CTD, which is a function of stomatal conductivity, has been proposed instead of stomatal conductivity, since its measurement is easier and gives an idea about canopy rather than leaves (Amani et al., 1996). High stomatal conductivity results in cooler vegetation due to rapid water loss (water consumes energy during evaporation). Positive relationships were found between CTD and yield in wheat under heat stressed conditions (Reynolds et al., 1994; Amani et al., 1996). It has been demonstrated that by selecting a cool canopy, yields can be increased in stress-free settings (Van Ginkel et al., 2004). Because plant cooling ability is influenced by a wide range of physiological characteristics, it is a trait that incorporates all of these characteristics. In the wheat breeding process, CTD is essential because of its strong connection with yield in hot and dry conditions (Rashid et al., 1999), its high inheritance, and its appropriateness for selection in early generations. Along with stomatal conductivity, the transpiration rate is determined by meteorological conditions (water deficit) and the amount of water in the soil, which is why CTD readings are not consistent under all situations. The CTD, which can be measured with an infrared thermometer, usually gives successful results when measured under irrigated conditions. In addition, it should be measured with the recommended devices and in the appropriate period. It is not recommended to measure during the heading and anthesis period. Studies show that CTD is more related to yield when measured during grain filling period (Reynolds et al., 1998; Bahar et al., 2011). CTD was associated with 60% of the total variation in grain yield in wheat segregation populations in arid and hot conditions (Trethowan and Reynolds, 2007). Plant temperature was determined by Cossani et al., (2012) as the ideal physiological selection criterion in many respects related to water uptake and transpiration mechanism. There is a positive association between CTD and yield during the heading time, CTD may be utilized as an important selection criterion in heat resistance breeding programs, and durum wheat cooler than bread wheat during hot weather (Bahar et al., 2005).

In addition, low canopy temperature under heat stress was associated with an increase in stomatal conductivity and indirectly related to an increase in radiation utilization efficiency in wheat genetic resources. While grain production and heat tolerance were shown to be significantly linked with photosynthetic rate and stomatal conductivity, similar tendencies were not identified for CTD (Koç et al., 2008a). Royo et al. (2002) also discovered no significant variations in CTD. For this reason, first of all, it is necessary to determine under which conditions this feature can be used more effectively.

Along with the photosynthetic system's capacity, the duration of this capacity (stay-green) is critical, especially under stressful situations. This situation can be examined by monitoring the change in chlorophyll content at certain intervals during the maturity process. However, since chlorophyll content measurements are laborious and time consuming, the capacity and continuity of the system can be determined indirectly with instruments (SPAD, spectro-radiometers) that measure according to the light reflected, transmitted or absorbed from the leaf. It has been reported that there is a linear relationship between SPAD values and the amount of chlorophyll content in the leaves at the time of reading. Despite a strong year x variety interaction, SPAD values were connected with photosynthesis in new generation Mexican bread wheat cultivars, whereas they were related with photosynthesis and enhanced yield in durum wheat (Yildirim et al., 2011; Barutcular et al., 2015 and 2016; Silva-Pérez et al., 2020). Giunta et al. (2002) demonstrated that when SPAD values are combined with leaf area in durum wheat, they can be used to select lines with high photosynthetic activity without reducing leaf area. Yildirim et al., (2009) showed that SPAD values could be used as selection criteria to define high yielding breeding lines at early segregation of progenies. A meaningful correlation was found between the grain yield and SPAD readings that were taken on seedling stage during heat stress (Toptaş et al., 2016b).

Chlorophyll fluorescence, which represents photosynthetic activity, emerges as a supportive breeding criterion in wheat breeding for stressed conditions. Under stressful conditions, the rate of photosynthesis decreases due to CO_2 diffusion and biochemical processes, as well as damage to the photochemical system. It is known that the PSII system, where several chlorophyll compounds serve as light-capturing agents and chlorophyll 680 is the reaction center, is especially susceptible to environmental stress (Allakhverdiev et al., 2008; Zmani et al., 2018). The amount of light absorbed by pigments but that cannot be utilized because of stress and is returned to outside by the PSII system is called chlorophyll fluorescence and indicates how much stress is there (Krause and Weiss 1991). The most important components of chlorophyll fluorescence are Fo (the amount of fluorescence when Qa in the Plastoquinone electron acceptor system is completely oxidized, in other words, when the electron deficit is highest) and Fm (the amount of fluorescence when Qa is temporarily completely reduced) and Fv (Fm - Fo) calculated according to these, and the Fv/Fm ratio showing the energy use efficiency of the PSII system. Although it has long been known that fluorescence parameters can be used as supportive breeding criteria in bread and durum wheat in dry and hot conditions (Dew Kumari et al., 2012; Man et al., 3017), Araus et al.,(1998a and 1998b) showed that Fo and Fm values measured during the grain growth period in durum wheat varieties grown in arid conditions are closely related to yield, and these values can be considered together with other criteria since they can be masked due to differences in phenological development.

Today, methods based on the measurement of light of different wavelengths reflected from the vegetation and which provide the opportunity to evaluate all the above-mentioned leaf and vegetation physiological measurements at the same time are emphasized. These types of measurements allow the measurement of seasonal variation as well as the instant measurement of physiological activity at the single plant and canopy level (Araus, 1996; Araus et al., 2001). In Figure 5, the regularly used spectral areas are shown. It is important to emphasize that while measuring crop canopies, most focus is placed on electromagnetic radiation that is within the visible (VIS) and near-infrared (NIR) sections of the electromagnetic spectrum (350 nm-750 nm and 750 nm-2500 nm, respectively) (Figure 6). Differences exist in the reflectance (R, spectral reflectance) of the light reflected by canopy due to the physiological responses of plants and canopy to various environmental situations such as drought and high temperature. Developments in radiation measurement technology have allowed the measurement of different reflectance values and detailed evaluations at the canopy level according to the calculated indices. These indices can be used to forecast with high precision the stress level of the canopy and grain yield. It has been shown that these indices calculated according to different reflectance values can be used successfully in

Mediterranean conditions with low yield potential and leaf area (LAI) index less than 3 (Aparicio et al., 2000a). Normalized difference vegetation index (NDVI), the most widely used of these indices, has been successfully used to determine photosynthetic activity, plant health and plant productivity (Reynolds et al., 1999; Kızılgeci et al., 2021). NDVI is useful tool for measuring agronomic responses of wheat to multiple environment (Fig. 7). NDVI, on the other hand, must be seen as a composite measure of plant development that represents numerous plant growth variables, rather than as a single metric. In wheat, for example, NDVI values during the late booting stages were linked to grain yield (Karaman et al., 2014). Without awareness of the fundamental reason that restricts growth, the underlying factor for variability in a typical vegetation index cannot be blindly connected to an input. For example, when heat stress is restricting development in a particular area, the NDVI may be highly correlated with heat tolerance.

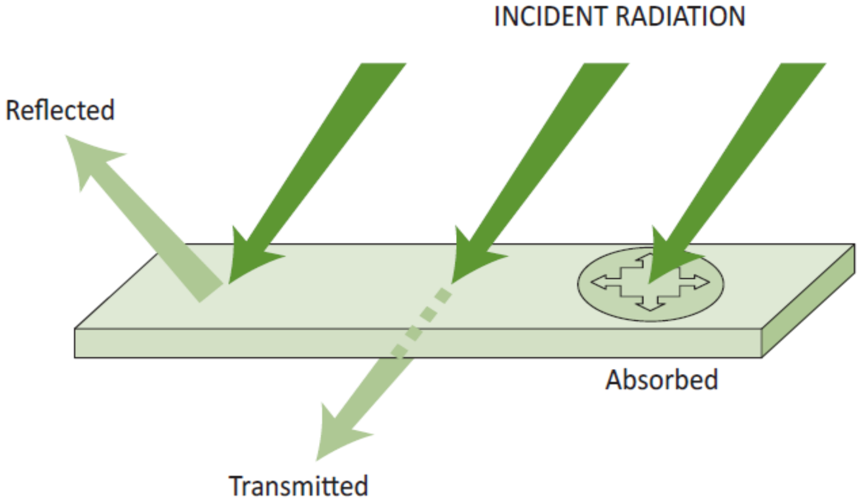

Figure 5. Incident radiation is equal to reflected radiation + absorbed radiation + transmitted radiation (data from Mullan, 2012)

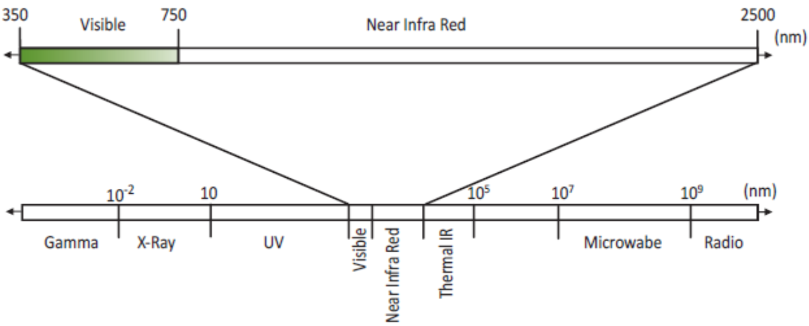

Figure 6. Range of the electromagnetic spectrum, with the region measured using canopy spectral reflectance indices enlarged above (data from Mullan, 2012)

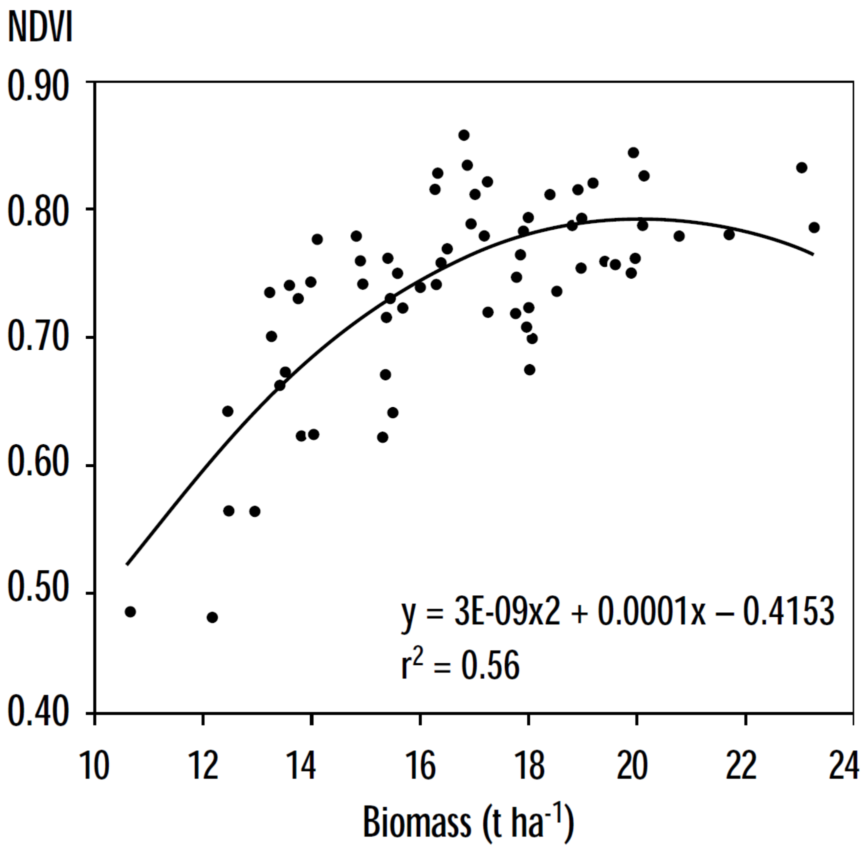

Figure 7. Relationship between NDVI and biomass of spring wheat advanced lines (Reynolds et al., 1999)

One of the most powerful physiological features used to determine the resistance of plants to heat stress is the membrane thermostability (MTS) measurements, which show the ability of all membrane systems in the cell to maintain their selective permeability properties. A working membrane system appears to be necessary for plants to adapt to higher temperatures. MTS shows how long the membrane system can maintain its selective permeability, especially under hot stress conditions. Maintaining the selective permeability features of membrane systems under stressful situations is required for normal physiological function to continue (Blum, 1988). Heat damage to plasma membrane destroys membrane integrity causing solute leakage from the cells. Increased solute leakage is an indication of decreased cell membrane thermostability, and has long been used as an indirect measure of heat-stress tolerance in diverse plant species, including wheat (Blum et al., 2011). It is calculated by the amount of electrolyte (solute) that the leaf exposed to stress has passed into pure water. It is frequently stated that MTS gives precise results in heat resistance and is one of the important properties that can be used in grains under stress conditions (Tripathy et al., 2000; Yildirim et al., 2009a; Bala and Sikder 2017). However, MTS also suffers from the issue of large variation, which is typically seen when measuring physiological characteristics. It has been suggested that these tests be performed during the seedling development period under controlled conditions to reduce variation (Reynolds et al., 2001).

2.4. Remobilization

Mobilization of the reserves accumulated in the stem to the grains provides a significant advantage in stressed conditions. When the physiological and biochemical events of assimilating production are affected under stress, the potential of previously accused reserves in the plant and utilizable for grain growth and their re-mobility to grain under hot conditions gain in significance. The excessive photosynthesis products are accumulating in reserve form (TNC, total non-structural carbohydrates, fructose and simple sugars in wheat) (Koç and Nösberger, 1987) shortly after flowering in plant, and can be used at later stress period in grain growth via transportation (remobilization). Since the direct measurement of the amount of remobilization is difficult and much time consuming, the amount of remobilization can be determined by comparing the amount of accumulation (weight) to the grain in the desiccant applied and non-desiccant conditions (Blum et al., 1983). Macronutrient remobilization models in grains can be beneficial for identifying plants with a high capacity for nutrient accumulation under stressed conditions. Studies based on direct measurement have shown that the amount of macro and micro elements in all plant organs is reduced and transported to the grain during the grain filling period (Tiryakioğlu et al., 2013 and 2014). It should also be noted that transport is associated with the senescence process (Figure 8). The contribution of the reserves can also be estimated from the difference in stem weight at flowering and physiological maturity without taking into account respiratory losses.

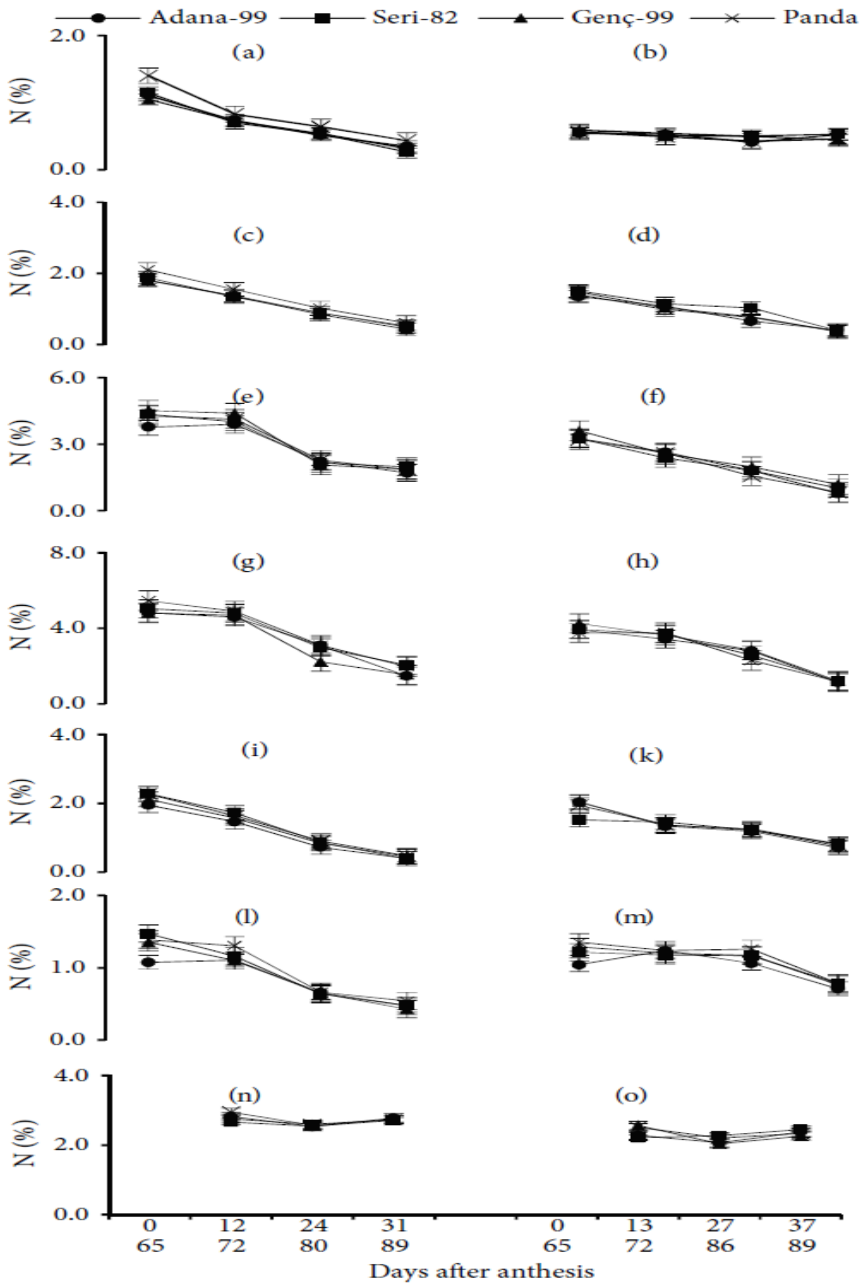

Figure 8. Changes in N content measured in different plant organs (a–b: lower stems, c–d: peduncle, e–f: lower leaves, g–h: flag leaf, i–j: rachis, k–l: florets, and m–n: grain) from anthesis to grain maturity for wheat genotypes in 2009 (left figures) and 2010 (right figures) (Tiryakioğlu et al. 2014).

2.5. Protective Enzymes, Metabolites and Proteins

An increase in reactive oxygen species (ROS) and its amount are observed in plants under stress. Compounds such as superoxide (O-), hydroxide (OH-), hydrogen peroxide (H_2O_2) cause oxidative stress, which causes the breakdown of membrane structures and macromolecules in the cell. Cells that can eliminate the generated ROS by means of many enzymes such as superoxide dismutase, catalase, ascorbate peroxidase and glutathione peroxidase can maintain their vitality (Table 2) (Lee and Lee, 2000). Antioxidant mechanisms play an important role in the response of plants to heat stress. Antioxidants such as non-enzymatic tocopherol, ascorbic acid, glutathione, and carotenoids degrade ROS in addition to these (Table 2). The increase in the amount of ROS with stress is toxic and harmful for the cell. Therefore, measurement of enzymes and antioxidants that resist ROS, especially in high temperature stress, may be effective in explaining the heat resistance mechanisms in wheat genotypes and in genotype selection. Abiotic stress causes reactive oxygen species (ROS) production in chloroplasts and mitochondria by disturbing membrane stability and biochemical reactions, resulting in photorespiration and enzymes involved in cellular respiration (Jaspers and Kangasjarvi, 2010). Meanwhile, antioxidant activities decreased in drought susceptible genotypes and increased in heat tolerant genotypes (Daud et al., 2012). Therefore, identification of non-enzymatic and enzymatic systems may be correlated with stress and could be used as indicators of stress tolerance. So the integration of conventional breeding with the above mentioned antioxidants as screening criteria offer new opportunities for improving stress tolerance in wheat. By understanding the correlation between antioxidants activities and yield attributes we can develop efficient screening method able to screen large amounts of plant material in the shortest time possible (Suzuki et al., 2012).

As a result of molecular and physiological reactions, plant species experience growth reduction/stagnation as well as water loss, yield loss, and other negative consequences of stress. When high temperature stress is detected, the production of Ca-dependent protein kinases (CDPKs), mitogen-activated protein kinases (MAPK/MPKs), NO, sucrose (as a signal molecule), and phyto-hormones increases. Transcription factors and these genes activate stress response genes (Hasanuzzaman et al., 2013). High-temperature-shock genes (Heat Shock Genes-HSG) are activated during stress, enabling the synthesis of high-temperature proteins (Heat Shock Proteins-HSP). These proteins are required for the plant to survive under conditions of heat stress, and several classes of HSPs perform a variety of tasks. A large number of microRNAs (miRNAs) have been shown to be involved in the temperature tolerance mechanism of wheat (*Triticum aestivum* L.), and six novel miRNAs have been identified and confirmed by Kumar et al. (2015). Furthermore, according to Liu et al. (2015), the transcription factor rose and reduced in a comparable manner between 64.3 percent and 82.9 percent in temperature, drought, and heat+drought trials, respectively. In a similar vein, Xue et al. (2015) discovered that increasing the expression of the TaHsfA6f transcription factor in response to high temperature stress resulted in an increase in

HSPs. As a consequence of the research, they discovered that TaHsfA6f, which acts as a transcriptional activator, regulates the TaHSP, TaGAAP, and TaRof1 genes, and that this gene pathway has a favorable influence on wheat's ability to tolerate high temperatures. TaWRKY1 and TaWRKY33, two WRKY transcription factor genes, were shown to be upregulated under high temperature conditions, according to He et. al, (2016). WRKYs are known to play a significant role in stress tolerance, both in wheat and other plant species (Arabidopsis thaliana, Oryza sativa). It has been observed that a vast number of transcription factors, genes, quantitative trait loci (QTLs), and other factors are involved in the tolerance of many species to high temperature and/or drought stress, particularly in model plant species.

2.6. Agronomic Applications

By supplementing both micronutrients and macronutrients, we may modify stomatal opening and closing promote metabolic and physiological processes, and boost heat stress tolerance (Waraich et al., 2012). The following are the most often utilized micro and macro elements: Mn (manganese), Se (selenium), and B (boron) as well as K (potassium) and Ca (calcium). The antioxidative defense mechanism can be made stronger by exogenous application of macro and micro nutrients.

Applying mulch helps to reduce the soil temperature by keeping it cooler. Mulches made from organic materials slow heat transfer to the soil surface by holding on to incoming solar energy (Komariah et al., 2008). Decreasing the maximum soil temperature while increasing the minimum are all part of this mulch's ability to control soil temperature (Begum et al., 2001). Plastic film mulching, which lowers soil heat loss by retaining heat in the soil, improves plant development and increases agricultural yields.

Biochar treatment had a positive effect on water and heat resistance, and drip irrigation's conventional method of coordinating heat and drought was further enhanced (Ding et al., 2019). Studies show that biochar application can influence the soil properties due to its physicochemical properties. Studies show that organic amendments such as biochar can influence the transformation of N in the soil due to its physicochemical properties (Awasthi et al., 2016). Thus, biochar is projected to offer good impacts on soil temperature and plant nutrition in wheat by lowering soil temperature. It is indicated that heat and drougt tolerance in wheat cultivars is enhanced by introducing charcoal, zeolite, and mulching into soil and nutrient amendments, especially when plant is at anthesis and booting stages (Zahra et al., 2021).

In addition to the treatment options for stress, a few holistic techniques may also be used to assist control the challenges associated with heat stress. These strategies include plant growth stimulants in conjunction with priming and foliar application. Farooq et al. (2018) found that priming exogen application to wheat with a foliar spray of water extract from brassica, sunflower, or moringa, helped increase transpiration efficiency, water use efficiency, total soluble phenolics, chlorophyll content, biomass, and grain yield under drought and stress in wheat.

It is an intriguing field of agricultural study for improved plant resistance to abiotic stress, where the potential of root-colonizing endophytes to increase the resilience of their hosts is discovered. Increased plant drought tolerance is possible by virtue of asco-or basidiomycota endophytic interaction with both below-and above-ground plant tissues (Redman et al., 2002; Hubbard et al. 2011). Mycorrhizal symbiosis has been found to help plants tolerate heat stress and elevated temperatures (Zhu et al., 2017). The putative mycorrhizal symbio-sis mechanisms include potentially improved environmental stress tolerance for the host plants via improved water and nutrient consumption, improved photosynthesis and efficiency, plant protection against oxidative damage and higher osmolyte storage. Under high and low temperature stress, mycorrhizal -inoculated barley had larger shoot biomas than the non- mycorrhizal plants.

Polyamines (PAs) like putrescine (put), spermidine (Spm) and spermine (Spm) are defined as intracellular plant growth regulator(s) regulating plant growth, plant development and responses to abiotic stress (Shi and Chan 2014). In this instance, exogenous Spermine and Spermidine administration relieved the heat harm on wheat filling (Jing et al., 2020). Also, exogenous cytokinins has positive effect grain yield of winter wheat cultivars by improving stay-green characteristics under heat stress (Yang et al., 2016). Abscisic acid (ABA) has been shown to be involved in heat tolerance modulation in wheat. Exogenous ABA increased grain yield by increasing the grain sink capacity and grain filling rate by regulating endogenous hormone contents to promote endosperm cell division and photosynthate accumulation in both normal and high temperature stress conditions (Yang et al., 2014). Besides the endogenous components mentioned above, there is a significant need for further study on plant homogenes, metabolites, amino acids, and chemical compounds, which can be employed to enhance heat resistance in wheat.

Crop cultivation practices can minimize the adversities of heat stress; however, the literature contains little information on useable growing techniques heat tolerance in wheat cultivars. In order to produce wheat successfully in heat stress conditions, correct cultivation procedures such as planting date, plant nutrient treatments, seed priming, foliar spraying of osmo-protectant, soil moisture conservation and water management must be used (Fahad et al., 2017).

CONCLUSIONS

For high and stable yield in stress conditions that we cannot control, the development of suitable varieties for these conditions should be taken into consideration for the better yield. Concerns about food production in harsh climate conditions in the future indicate that variety development efforts will gain more importance. The combination of both molecular and high-through put phenotyping technologies is important for the improvement of crops under abiotic stresses. It is also important to reduce the detrimental effects of heat stress on wheat by using agricultural management techniques and treatments.

Table 1. Physiological traits that can be employed in wheat breeding in hot climates.

Traits	References
Gas exchange	
Photosynthesis rate	Al-Khatib and Paulsen, 1984 Reynolds et al., 2001 Shah and Paulsen, 2003 Koç et al., 2008
Stomatal conductance	Araus et al., 1993 Reynolds et al., 1994 Reynolds et al., 2001 Ayeneh et al., 2002 Koç et al., 2008 Pinto et al., 2008
Cuticle conductance	Reynolds et al., 1998
Radiation spreading, reflecting, transmitting,	
CTD	Reynolds et al.,1994 Amani et al.,1996 Reynolds et al.,2001 Ayeneh et al., 2002 Bahar et al., 2008 Yildirim et al.,2009b
Chlorophyll fluorescence	Moffat et al., 1990 Balota et al.,1996 Elhani et al., 2000
Chlorophyll and other photosynthetic pigments	Araus et al., 1998b Reynolds et al.,2001 Tahir an Nakata, 2005
Carbon 13 isotope discrimination (grain)	Sayre et al., 1995
Ash content (leaf)	Koç et al., 2008

Remobilization	Blum, 1998 Tahir ve Nakata, 2005
MTS	Saadala et al.,1990 Shanahan et al., 1990 Blum et al., 2001 Reynolds et al.,2001 Yildirim et al.,2009a

Table 2. Some of the most important heat stress proteins and antioxidants appear during heat stress.

Antioxidants	Heat Shock Proteins
Enzymatic	HSP100
SOD	HSP90
CAT	HSP70
GPX	HSP40
APX	Small HSPs
Non-enzymatic	
Ascorbic Acid	
Glutathione	
Tocopherol	
Caratenoids	

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CHAPTER 3

THREE IMPORTANT ABIOTIC STRESSES (DROUGHT, HIGH TEMPERATURE AND SALINITY) AFFECTING WHEAT

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INTRODUCTION

Wheat is an essence crop for a major ratio of the world's population. Wheat growing began about 12,000 years ago and now occupies more area than any other trading crop. Today, wheat varieties have been developed that produce flours used in various foods such as bread, pasta, breakfast cereals and biscuits.

Abiotic stresses often have negative effects on plant growth and development and therefore reduce plant yield. In the field, crops are normally exposed to one or a combination of two or more abiotic stresses. Critical abiotic stresses that crops are often subjected to include drought, high temperature, salinity, and nutrient deficiencies. The most widespread stresses have in common their effect on plant water status. Water availability is a crucial factor in defining the impact of climate change in many places (Kurukulasuriya, 2003).

1. Response of Wheat to Drought

1.1. The effect of water restriction on wheat developmental stages

A large part of world agriculture is carried out in water stressed regions of the world. The hydrological regimes in which agriculture is practiced change day by day with global warm. In many environments, water supply is a great source of variability in crop yields. It is globally accepted that rainfall is a leading factor effecting, especially, rain fed crops' productivity (Lin et al., 2005).

The crops grown is affected by many out-of-control climatic factors, the number one being rainfall. The amount and temporal distribution of precipitation is often the most important determinant of annual fluctuations in crop production levels, and rainfall plays a more important role in wheat production than other farm inputs (Hu et al., 2009).

Water is an abiotic factor and an important limiter affecting plant growth, development and productivity. The response of plants to water stress depends on plant species, plant age, growth and development period, drought level and continuity, and physical factors. Plants have developed different morphological, physiological and biochemical responses to prevent or get rid of the negative effects of stress (Marcińska et al., 2013).

The drought stresses that occur in different growth periods of wheat have different effects on yield, yield components and plant nutrient uptake. The early drought stress significantly reduced the nitrogen (N) uptake by 38% while late drought stress decreased nitrogen uptake by 46%. The phosphorus (P) and potassium (K) uptake were decreased by 49% and 37% under early drought stress, respectively while their uptake was decreased by 51% each under late drought stress. Grain yield was reduced by 24% under early drought stress while it was reduced by 60% under late drought stress. Water deficit at early growth stages reduced grain weight by 10% while it was reduced by 35% under water deficit at later stages of growth (Navaz et al., 2012). The recovery of wheat yield after drought stress during tillering depended on preserving the number of seeds in the spikes developed under stress and producing a large number of spikes upon recovery. As the drought stress developed towards the later tillering stage, yield recovery was weakened as the number of grains per ear and tillering after recovery decreased (Blum et al., 1990).

Wheat needs water in all its development stages, but in some periods, lack of water is very important and causes vital yield losses. Especially, lack of water causes significant yield losses during pregnancy and early grain filling. Some researchers emphasized that the lack of water during the spike formation period has a significant effect on the grain yield (about 36%) and the total yield (about 20%) (Aghanejad et al., 2015).

Terminal drought in wheat shortens the grain filling process and life cycle. In arid conditions, the grain filling rate decreases due to decreased photosynthesis and accelerating leaf senescence. The first sign of leaf aging is chlorophyll breakdown and a decrease in photosynthesis (Saeedipour and Moradi, 2010).

Figure 1. Drought during the earning period for wheat

Terminal drought has more effect on grain number than grain size. This situation leads to a decrease in wheat yield in arid conditions. Meiosis and pollination are extremely sensitive to drought, and its adverse effects directly affect the number of grains and cause significant reductions in grain yield. Wheat genotypes give a better yield by maintaining flag leaf photosynthesis for a longer time. Therefore, the aging rate and initiation of the flag leaf in wheat is an important factor in studying drought stress resistance. Terminal drought encourages aging in wheat, but remobilization increases during the pollination period, carbohydrates accumulate in the growing grains in stems and leaves, causing a decrease in grain yield based on aging (Farooq et al., 2014).

With the increase in drought severity, photosynthesis rate, water content, plant height, grain filling process, number of spikes, grain number per spike, 1000-grain weight significantly decrease (Samarah et al., 2009).

Post-flowering drought stress decreases wheat grain yield, 1000 grain weight and flag leaf area (Kanani et al., 2013). Severe drought stress causes early death in leaves, leading to a significant decrease in photosynthesis and thus yield losses (Anonymous, 2015). Possible yield losses during the grain filling period may be caused by incomplete grain, reduced grain weight and early plant death.

1.2. Approaches to increase yield in wheat in limited water conditions

There are also various approaches to investigate morphological properties in order to increase yields in limited water conditions. Leaf curl caused by turgor loss and poor osmotic adjustment represents an important drought avoidance mechanism (Richards, 1996). In drought conditions, leaf rolling reduced stomatal closure (O'Toole et al., 1979b).

Wheat genotypes that exhibited strong leaf rolling under water shortage condition had more grain yield, kernel numbers per spike and water use activity (Bogale et al., 2011).

Figure 2. Wheat varieties response to drought

Peduncle length which have been found a strong positive correlation between peduncle length and grain yield has been also suggested as useful indicator of yield capacity in dry environments (Kaya et al., 2002).

Higher stomatal resistance reduces transpiration loss and hence can improve water use efficiency of the crop under water limited conditions (Munir et al., 2007).

1.3. External Applications Used to Tolerate Drought in Wheat

1.3.1. Plant growth regulators and some osmotic preservatives

External application of various plant growth regulators and some osmotic preservatives such as cytokinin, abscisic acid, proline, glycine betaine, polyamine and salicylic acid have a significant potential to increase drought tolerance in wheat (Travaglia et al., 2007).

Kinetin applied externally in wheat increases the chlorophyll content of the flag leaf, which is an important tolerance parameter in wheat in dry conditions (Yang et al., 2003). Externally applied sodium nitroprussite provides resistance to drought stress in wheat during grain filling by supporting antioxidant enzyme activity and preservation of important gene transcriptions in PSII.

External application of glycine betaine to wheat flag leaf under terminal drought stress conditions increases the stomatal conductivity and gives a higher net photosynthesis rate. Plants treated with foliar glycine betaine have higher photochemical activity and less oxidative damage (Ma et al., 2006). In another study, external glycine betaine application protects the photosynthesis mechanism in wheat by improving yield (Sing and Usha, 2003).

The application of salicylic increases the durability of wheat in arid conditions. Treatment with salicylic acid in wheat prevents the decrease in indole acetic acid and cytokinin content by reducing stress-based inhibition (Sakhabutdinova et al., 2003).

Root application of ascorbic acid to wheat plants exposed to drought is an effective way to deal with the negative effects of drought stress. Plants treated with ascorbic acid show higher photosynthesis rate, transpiration and stomatal conductivity (Malik and Ashraf, 2012).

1.3.2. Plant nutrients

Potassium mitigates the harmful effects on plants by providing drought tolerance, water balance and increasing translocation. Potassium plays an important role in processes such as osmoregulation, photosynthesis, transpiration, stomata opening and closing, and protein synthesis in plants. The negative effect of drought on wheat development is reduced with potassium application, and an increase in yield can be observed by sending potassium to other organs. Lack of water seriously limits growth and yield in wheat in each critical development period. Foliar potassium application improves all yield components in all developmental stages, and the grain filling period is observed to be very sensitive to this situation (Aown et al., 2012). Plants absorb nutrients more easily with foliar application and yield increase.

Silicon (Si) application reduces water losses by reducing the cuticular transpiration rate in plants in arid conditions. With the application of silicon in dry conditions, better water content and more dry matter accumulation were observed in wheat compared to control conditions (Ma et al., 2006). Silicon application significantly increased plant biomass, plant height and spike weight at all levels of water contents (at three levels of soil water contents viz 50%, 75% and 100% of field capacity). Poor growth of plants in water deficient conditions was significantly improved with Si application (Ahmad et al., 2007).

Selenium application also has an important potential in regulating the plant water content in dry conditions and ensures that the water content in the plant tissues remains in the desired amount. Under arid conditions, the protective effect of selenium is achieved by increasing the water uptake ability in the root system. By reducing selenium peroxidase activity, it prevents proline accumulation based on stress (Kuznetsov et al., 2003).

Selenium applied to wheat in dry conditions alleviated drought stress by improving the rate of photosynthesis in the plant, protection of leaf photochemical events, organic osmolyte accumulation and water use efficiency (Hajıboland et al., 2015).

The normal plants fertigated with Se maintained the highest values for number of productive tillers, spike length, number of grains per spike, thousand-grain weight, biological and grain yield with no significant difference from Se foliar spray at the tillering stage, which was found to be the most effective method of exogenous Se supply for improving wheat yield under water deficit conditions (Nawaz et al., 2017)

Droughts occurring during the flowering and grain filling period in many plants prevent the intake of nutrients from the roots and this situation causes low micronutrient content and yield losses in cereal grains. Soil moisture plays an important role in providing nutrients to plant roots. Foliar zinc, manganese and boron applications to winter wheat under drought stress increased the grain yield. Foliar application increases water use efficiency and the content of micronutrients in the grain, resulting in an increase in photosynthesis, pollen vitality, fertile spike number and grain number per spike. This situation encourages micronutrient application in areas with limited water, especially in arid and semi-arid regions (Malik & Ashraf, 2012).

2. Response of Wheat to Extreme Temperatures

Increased hot and cold spells resulting from climate change could affect bread-making quality or seed quality for growing subsequent wheat crops, depending upon when they occur. The negative effects of heat on plant yield strongly depend on its duration and the phonological stage of the crops when the heat occurs. A better understanding of the impacts of mean temperature changes on wheat precedes consideration of the effects that changes in climatic variability and extreme conditions might have on wheat. Temperatures that lie except the range of those typically experienced can have violent consequences for crops, significantly reducing yields. Both high and low temperatures decrease the rate of dry matter production and, at extremes, can cause production to cease.

2.1. Effects of extreme temperatures in the vegetative stage of wheat

In plants, the basic temperature is the temperature at which development stops in the cold. As the temperature rises above the base, the process gradually speeds up until it reaches the optimum temperature. Optimum is the temperature at which growth is fastest (Figure 1). Temperatures higher than optimum can slow growth and at temperatures well above optimum growth may stop completely and the plant may die. For wheat, base and optimum temperatures aren't any time 0° C and 25° C respectively. They actually start lower temperatures and rise with development. Varieties differ in their base and optimum temperatures. In general, winter wheat can develop at lower temperatures than spring wheat.

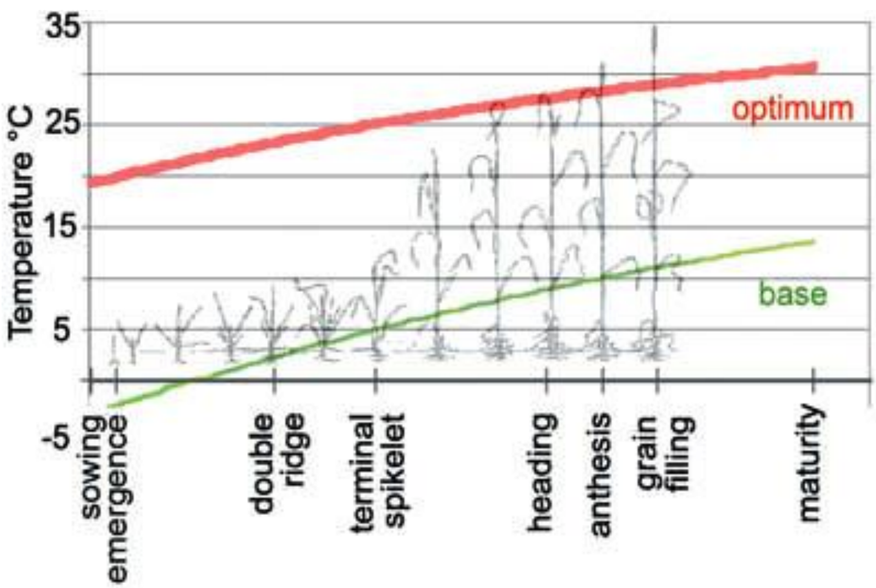


Figure 3. Change in optimum and base temperature with development

The high temperature from emergence to anthesis significantly decreased duration of all the development stages (emergence to double-ridge, double- ridge to anthesis and anthesis to grain maturation) in wheat (Blum et al., 2011). However, duration of double- ridge to anthesis was the most sensitive phase to high temperature. The double-ridge phase is immensely susceptible to high temperature stress, as the high temperature in the double ridge stage damages the development of spikelet primordial in the apex (Johnson and Kanemasu 1983).

2.2. Effects of extreme temperatures in the reproductive stage of wheat

High temperature stress during reproductive development is a big restriction to wheat production in most parts of the world. Wheat plant is more damaged when high temperature stress occurs in the reproductive stage than the vegetative stage due to the direct negative effect of high temperature on the grain number and grain weight (Wollenweber et al., 2003; Hall, 1992).

Low temperature in reproductive stage of spring wheat causes infertility of pollen grains and a decrease in yield. The lower average temperature during the crop growth period led to enhanced the crop growth period in both aestivum and durum varieties of wheat crop. This causes in decreased pollen germination and lower yield in the wheat crop. While pollen germination is maximum between 18°- 20°C temperatures, the pollen germination decreases in many wheat varieties at lower temperatures. Studies showed that low temperature in the breeding phase can limit the yield of wheat by affecting the phenology and productivity of pollen grains.

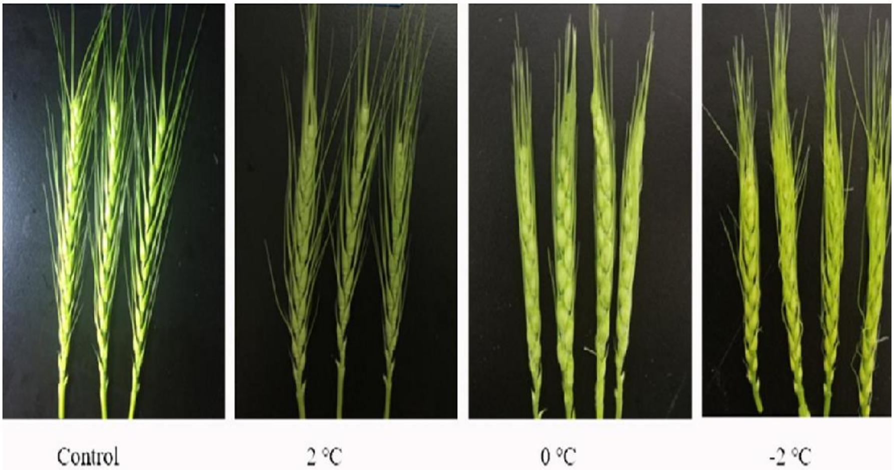


Figure 4. Effect of low temperature on the morphology of wheat ears at booting stage. (Original photo- graphs taken by one of the author W. Zhang)

In regions where the temperature is very low, adaptation measures should be developed to reduce the yield loss of wheat in the anthesis phase (Chakrabarti et al., 2011). To increase membrane stability, plants accumulate large amounts of carbohydrates at low temperature, causing stomatal closure, photosynthetic electron transport damage, and inhibiting carbon assimilation (Li et al., 2014). Low temperature stress also reduces the feeding of soluble carbohydrates to reproductive tissues, leading to nutrient deficiencies in the tapetum and endosperm (Nayyar et al., 2005).

The increase in global mean winter temperatures promotes winter growth, increasing cold vulnerability in the spring (Li et al., 2016). Low temperatures in spring generally occur between the end of March and beginning of April, during which time wheat ears are in a critical period of meiosis and tetrad formation and are, therefore, highly sensitive to temperature stress. If exposed to low temperature at this time, the all wheat spike or parts of the spikelet will fail to set after tassel formation, decreasing yield by 30–50% (Zhang et al., 2011).

Figure 5. Damaged wheat spikes when frost occurred at different time of earhead emergence. (Original photo- graphs taken by one of the author Dr. R. K. Sharma).

2.3. Effects of extreme temperatures in the pollen and ovule formation of wheat

The most heat-sensitive phase of reproductive improving in wheat is the period from the starting of meiosis in pollen or embryo sac mother cells to the early development of micro or megaspores. In the studies conducted, there was a 35% decrease in pollen vigor in wheat plants exposed to high temperature of 30 ° C for 3 days compared to ordinary temperature (20 ° C) (Saini et al., 1982; Jager et al., 2008).

The high temperature stress that occurs in the megaspore mother cells at the stage of meiosis leads to anomalous ovarian development with small or no embryo sac and decreased nucellus (Saini , 1984). Wheat plants are highly sensible to high temperature stress during the period between flower onset and anthesis. Minimum, optimum and maximum temperatures for successful anthesis in wheat were determined as 9, 18–24 and 31°C, respective (Russell and Wilson, 1994).

Grain number is a major component of yield in wheat. High temperatures in the spike period of wheat accelerate the development of spike and reduce the number of spikelet and grain per spike. 10°C increase in maximum temperature at mid anthesis caused 40% reduction in grain number per spike (Wheeler et al., 1996).

Table 1. Summary of mean of lethal minimum (*TL* min), lethal maximum (*TL* max), base (*T* min), optimum (*T* opt) and maxi- mum (*T* max) temperatures for various processes and phenological phases in wheat.

Processes		**Mean temperature (°C)**		
		***TL*min**	***T*opt**	***TL*max**
Lethal limits		−17.2 ±1.2		47.5 ± 0.5
		***T*min**	***T*opt**	***T*max**
Leaf initiation		−1.0 ± 1.1	22.0 ± 0.4	24.0 ± 1.0
Shoot growth		3.0 ± 0.4	20.3 ± 0.3	>20.9 ± 0.2
Root growth		2.0	<16.3 ± 3.7	>25.0 ± 5.0
Phenological phases	Sowing to emergence	3.5 ± 1.1	22.0 ± 1.6	32.7 ± 0.9
	Vernalization	−1.3 ± 1.5	4.9 ± 1.1	15.7 ± 2.6
	Terminal spikelet	1.5 ± 1.5	10.6 ± 1.3	>20.0
	Anthesis	9.5 ± 0.1	21.0 ± 1.7	35.4 ± 2.0
	Grain-filling	9.2 ± 1.5	20.7 ± 1.4	35.4± 2.0

Note: The data in the table is derived from the study of many manuscripts.

2.4. Effects of extreme temperatures in single grain weight

High temperature (32/27°C) from anthesis to maturity caused 20% reducing in average grain weight of wheat while high temperature

(40/21°C) during grain filling reduced single grain weight of wheat by 14%, compared to the control (21/16°C). High temperatures decrease the time period between anthesis and physiological maturity, which results in a reducing in single grain weight. A sudden rise in temperature (from 20 to 40°C) caused a major reduction in single grain weight in a heat sensitive wheat variety, but this trend was absent in the heat tolerant wheat variety (Hoshikawa, 1962). Grain filling period reduced by 2-8 d for every 1°C increase above 15–20°C in wheat (Streck, 2005)

Under optimum temperature conditions, the reduced grain filling time is compensated by increased grain filling speed, while this compensation does not occur under high temperature stress, resulting in a significant reduction in individual grain weight (Sofield et al., 1977). Decrease in leaf and spike photosynthesis and decrease in the regeneration of stem reserves are the main reasons for the decrease in grain filling ratio at high temperatures. Increased grain filling ratio is a useful feature that can be used to improve heat tolerance in wheat (Dias and Lidon, 2009). Grain yield was reduced by 78%, kernel number was reduced by 63%, and kernel weight was reduced by 29% at 35/20°C compared with 20/20°C from 10 d after anthesis until ripeness (Gibson and Paulsen, 1999). Based on a decrease in grain yield, *A. speltoides* Tausch and *A. geniculata* Roth were most tolerant wheat genetic resources for temperature tolerance.

In general, morphological traits like early ground cover, leaf rolling, biomass, and also several physiological traits, such as leaf chlorophyll content, photosynthetic rate, and flag leaf stomata conductance, membrane thermo stability, and stem reserves have been found to be associated with cellular thermo tolerance in wheat plants.

One way to reduce the effect of high temperature stress on yield is to develop stress tolerant varieties (Wahid et al., 2007). *Aegilops species* which are close relatives of bread wheat have been considered a genetic resource for increasing the genetic potential of cultivated wheat to withstand biotic and abiotic stresses.

Wild wheats are also sources for abiotic stress-tolerance genes. Some accessions of *A. tauschii, A. speltoides,* and *A. geniculata* Roth have shown the ability to resist drought (Baalbaki et al., 2006; Zaharieva et al., 2001).

Figure 6. *Aegilops geniculata* Roth

Figure 7. *Aegilops speltoides* Tausch

Based on a decrease in grain yield, *A. speltoides* Tausch and *A. geniculata* Roth were most tolerant to high temperature stress. Landraces preferred by local farmers are varieties that have been adapted to native environment and could be the potential sources high temperatures. Significant variability for higher temperatures has been noted among wheat varieties with higher leaf chlorophyll content (Dupuis and Dumas, 1990) and higher stomata conductivity' which can be used in breeding programs. In wheat, early heading varieties performed beter than later-heading varieties because they (i) produced fewer leaves per tiller and retained more green leaves, (ii) had longer grain filling periods, and (iii) completed grain filling earlier in the season when air temperatures were lower (Tewolde et al., 2006).

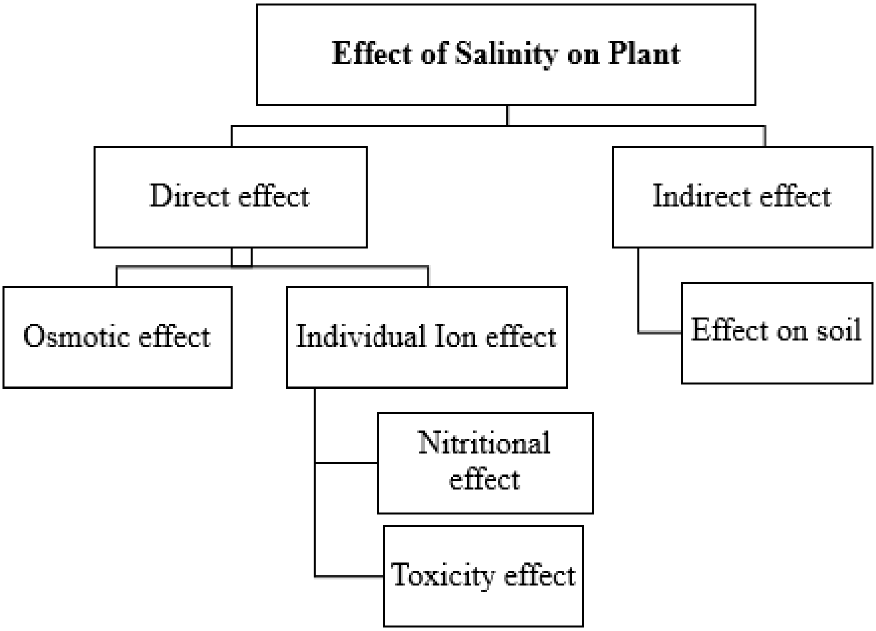
3. Response of Wheat to Salinity

Salinity, along with drought, is one of the most important stress factors that directly affect crop production and productivity in the near future (Parida and Das, 2005). It is estimated that 20% of the agricultural lands around the world will face salinity problem, and 50% by 2050 (Kang et al., 2010).

Salinity is one of the important problems that decreases plant diversity and agricultural productivity in our country as well as in the world. Especially in arid and semi-arid climatic regions, insufficient precipitation and high evaporation, insufficient drainage, wrong agricultural practices and soil properties are the leading causes of salinity and affect large areas.

Soluble salts in soil provide most of the elements necessary for plant growth, but their excess levels can be harmful. Saline soils are commonly found in arid and semi-arid regions where annual rainfall is insufficient to meet the evapotranspiration demand of the plants. Soil salinization is one of the important abiotic stresses which results in the reduction of growth and productivity of the crops (Sairam et al., 2002). Soluble salts can be easily taken up by plants. Salt compounds entering the plant structure are harmful to the plant when a certain concentration is exceeded depending on the type and amount.

Salinity has a toxic effect on the plant by disrupting nutrition and metabolism. Salts affect plant growth in three ways;



Physical impact; As a result of the increase in osmotic pressure, the plant's water intake and consequently nutrition slows down or stops completely. The plant has difficulty in water intake. This is also called osmotic pressure effect.

Chemical effect; Some salts make the intake of plant nutrients difficult and damage the plant's structure by disrupting the metabolism. This is also called the toxicity of specific ions.

Indirect Effects; Changes caused by salinity or sodium effects on the soil affect the growth of plants. Such as the use of metabolic energy to ensure water intake and a decrease in efficiency. (Munns and James, 2003; Ekmekçi et al., 2005). Osmotic effect causes disruption in osmotic potentials, where as specific ion effect causes toxicity of different ions (Brady and Weil, 2002). In addition, with the increase of salt concentration in the soil, the plant's water intake from the soil becomes difficult, the soil structure deteriorates and plant growth slows down or even stops ((Kanber et al., 1992; Güngör and Erözel, 1994). Although there is enough water in the soil, it has been observed that the plants have started to wither under some conditions. This situation generally arises from "physiological drought" caused by high soil salinity. In case of physiological drought, plant roots cannot take the water available in the soil owing to high osmotic pressure (Ayyıldız, 1990).

Studed research results show that salinity not only reduces plant growth and yield, but also causes nutritional imbalance and impairs grain quality. Salinity causes a significant decrease in grain protein, oil and fiber contents and yield components in wheat. Maximum reduction was noted in case of number of tillers plant^{-1}, followed by grain weight plant^{-1} (Abbas et al., 2013). Parida and Das (2005) stated that during the initiation and development of salt stress in a plant, all major processes such as photosynthesis, protein synthesis, energy production and lipid metabolism are affected. Disruption in these processes lead to a decrease in the yield and quality of wheat grains depending on the salinity.

Some studies showed that the decrease of leaf area is frequently the first signal of salinity stress (Volkmar et al., 1998; Acevedo et al., 2002; Çicek, 2002). Salinity also negatively affects root and root growth, but the shoot is generally more sensitive due to the inhibitive effect of salt on cell division and expansion in growing point, which, in turn, affects the normal growth of wheat and the viability of tillers and decreases the number of primary and secondary tillers. Many studies have reported that wheat is the most sensitive to salinity during germination and during tiller appearance (Ayers et al., 1952).

In wheat, tillering capacity is also reduced with increasing salt concentrations. The number of effective ears per plant has been determined as the most severely affected yield component in wheat under saline conditions (Maas and Hoffmann, 1977; Munns et al., 2006). In addition, salinity causes reduction in the number of leaves in the main shoot and reduction of the number of spikelets in the main spike, which result in reduction of seed set and grain yield (Maas and Grieve, 1986).

Salt stress is one of the main constraints of wheat production, and its impact is greater in durum wheat as this type is less salt-stress-tolerant compared to bread wheat. In addition, it has been determined that winter wheat was more tolerant to salt stress then spring wheat (Turki et al., 2012). In salinity studies in wheat, salt stress induces both anatomical and physiological changes in the stem and leaf cells of wheat, as well as the tissues and organs. Salinity caused reduction in the anatomical traits of stem and leaf diameter, wall thickness, diameter of the hollow pith cavity, total number of vascular bundles, number of large and small vascular bundles, bundle length and width, thickness of phloem tissue (Rania et al., 2020).

3.1. There are several approaches to increasing the salt tolerance of wheat.

- By introducing genes for salt tolerance into adapted cultivars, including screens of large international collections, detailed field trials of selected cultivars, conventional breeding methods, and unconventional crosses with wheat relatives.
- Use of plant growth regulators that promote haloalkaliphilic bacteria in wheat.
- Improving soils with high salinity by washing,
- Washing the highly soluble salts in the root area of the plants to a concentration that will not harm the plants,
- Proper drainage in soils with high salinity,
- Control of fertilization and irrigation are among other measures to be taken against salinity.

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CHAPTER 4

SPEED BREEDING IN WHEAT

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INTRODUCTION

Wheat, which plays an important role in moving on the settled life of humans, is one of the most important cultivated plants in the world. Cultured wheat dates back to the Göbeklitepe civilization, which has ruins dating back to 12000 BC. Wheat, which is an important figure in our literary and social life, is the staple food source of human beings. It alone meets approximately 20% of the daily calorie need of humans (Kün, 1988).

Wheat, which has a wide adaptation ability, is produced in wide geography around the world (Singh et al., 2016). World annual wheat production is approximately 760 million tons (Anonimous, 2020a), while 20 million tons of wheat is produced in 7.3 million hectares in Turkey (Anonimous, 2020b).

Any increase in wheat production has great importance to meet the needs of the rapidly rising world population. In the first half of the 20th century, some improvement was achieved in wheat production by increasing mechanization opportunities and gaining new agricultural areas. Since the second half of the 20th century, an increase in the grain yield per unit area has been occured thanks to development of short varieties and agronomic practices called the green revolution (Hanson et. al. 1982; Kün, 1988). In this context, researchers have tended to studies to increase the grain yield per unit area. Therefore, plant breeding is great importance for food supply and safety.

Breeding is the art and science of modifying and improving the heredity of a plant for purpose (Poehlman, 1987). It is the way to change the hereditary characters of different genus, species and cultivars in a planned way by taking advantage of genetic and cytogenetic features (Gökçora, 1973). The quality of breeding studies has been changed with the advancement of genetic studies. Breeding institutions and programs have been established to develop varieties with more productive, quality, stable and resistance to biotic and abiotic stress conditions since the beginning of the 19th century.

Plant breeding requires significant labour and infrastructure and involves a long process. Development of a new variety requires about 10-15 years by using classical methods (Salantur, 2018; Sarkar and Aminul Islam, 2020). In addition to labour and mechanization costs, classical breeding process also in producing quick solutions to various problems such as fungal diseases. Therefore, shortening the breeding process is important in terms of reducing costs and finding solutions to problems in shorter period. Biotechnological methods developed by increasing technological possibilities have enabled researchers to work at the gene level and contributed to the shortening of the breeding process (Salantur, 2018; Chaudhary et al., 2020). Speed Breeding method introduced by Dr. Lee Hickey and his team at the University of Queensland in Australia allows significantly shorten the process for breeding.

SPEED BREEDING

The Speed Breeding method required a protocol that including artificially provided photoperiod, temperature and humidity level for the purpose. The basis of the method based on shortening the harvest time by accelerating the development of long day and neutral day plants via increasing photoperiod duration (Watson et al, 2018; Ghosh et al, 2018).

The result of the studies conducted under the leadership of Lee Hickey from the University of Queensland in Australia shows that speeding plant growth under artificial conditions enables researchers to obtain 6 generations per year in spring bread wheat, barley and chickpea, 3 to 4 generations per year in winter wheat and 4 generations per year in canola (Figure.1). After hybridization, obtaining homozygous lines from the segregating materials required 5 or 6 years to be complete, but the same process can be completed in a year by this method. (Watson et al, 2018; Ghosh et al, 2018).

SPEED BREEDING PROTOCOL

Photoperiod is one of the most important components of the method. In this method, daytime (light) duration is 22 hours, while the night (dark) period is 2 hours (Watson et al, 2018; Ghosh et al, 2018). Growth and development are accelerated by enabling the plants to perform photosynthesis for a longer period of time. The light intensity is adjusted to be 360-380 μmol m^2 at the ground level where the plants are placed, and 450-500 µmol m² at the top level of the grown plants (Watson et al, 2018; Ghosh et al, 2018).

In photosynthesis, plants obtain the required energy from light. Plants use light with a wavelength between 390 and 760 nm in the spectrum of light emitted from the natural light source Sun (Eriş, 2007).

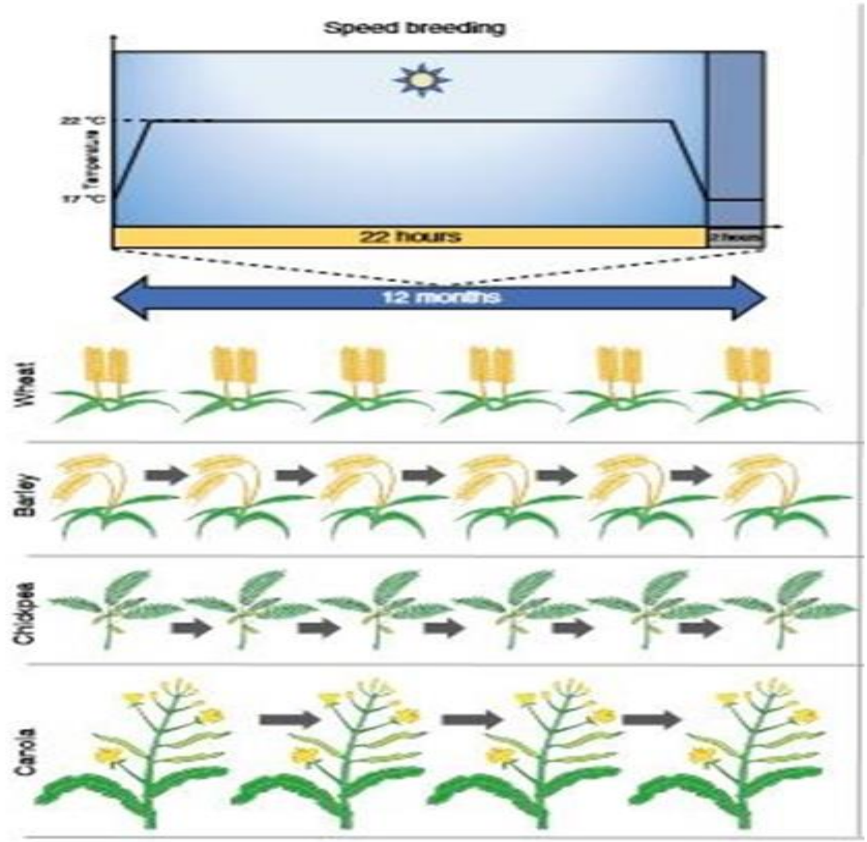


Figure1: Accelerates generation time of some crops in Speed breeding (Watson et al, 2018).

LED (Light Emitting Diode) lamps or high-pressure sodium vapour lamps can be used as a light source in a greenhouse or in a growth chamber established for Speed Breeding (Watson et al, 2018; Ghosh et al, 2018). LED lamps provide some advantages; they are economical in terms of energy consumption, do not emit ultraviolet or infrared light and do not contain harmful substances such as mercury.

Temperature is another important factor on plant growth in the speed breeding method (Went, 1953). According to the method, the temperature is applied as 22 ºC in the light period (22 hours) and 17 ºC in the dark period (2 hours). Suitable inverter split air conditioner can be used for heating and cooling, depending on the size of growth chamber (Watson et al, 2018; Ghosh et al, 2018; Anonimous, 2019). When choosing the air conditioner, the decision should be made by considering weekly or monthly programming feature and the heat emitted from the LED lamps.

The humidity level should be adjusted to approximately 60-70 % in the growth chamber (Watson et al, 2018; Ghosh et al, 2018). Additionally, there should be a higher humidity level for disease studies in the breeding unit (Boshoff, 2019). Considering several studies, dehumidifier and humidifier are needed to keep the humidity level at the desired level in the environment.

A CYCLE IN SPEED BREEDING

In the speed breeding method, plants can be grown in viols or pots. The size of the viols or pots should be consistent to the purpose of the study. Viols with 28-cell (51x32x7 cm) are sufficient for the studies to carried out accelerate the generation. Potting soil or soil mix can be used as growing environment (Anonimous, 2020c).

Before sowing the plant, seeds are placed in petri dishes with filter paper to germinate and moistened with sterile water including 0.5 ppm gibberellic acid. Petries are kept at 3-4 ºC for 2 days, after that, the seeds are germinated at 21-22 ºC room temperature (Watson et al, 2018; Anonimous, 2020). Following 2-4 weeks of vernalization, the germinated seeds are planted in winter genotypes After germination (2 days), seeds are sown. (Anonimous, 2020c).

One week after sowing, the plants reach the 3-leaf stage. At the end of the fourth the plants begin to heading week (25-28 days) and flowering occurs at the end of the fifth week (35-38 days). The plants can be harvested approximately 2 weeks (49-51 days) after flowering. The spikes are dried at 30-37 ºC for 3-5 days in order to reduce the humidity of the seeds from the harvested plants (Watson et al, 2018; Anonimous, 2020c).

ADVANTAGES OF SPEED BREEDING METHOD

The most important advantage of the speed breeding method is the opportunity to significantly shorten the breeding process. In particular, the growing period is shortened by 2-3 times in the spring bread wheat (T. aestivum L.). In the former studies, even though it varies according to the genotypes, heading occured in 25-28th days and flowering occured in 35-39th days. It can be harvested aproximately 2 weeks after flowering. Thence, a generation can be harvested in about 60 days and

6 generations can be grown in a year. The situation is slightly different for winter wheat. Due to the vernalization need, the process takes a little longer time; thus, 4 generations can be supplied in a year approximately. According to some studies on several other plant species, 6 generations can be obtained for barley and chickpea plants per year and 4 generations for canola per year (Watson et al, 2018; Anonimous, 2020).

The most important and the longest stage of breeding studies, which takes about 5-6 years (Salantur, 2018; Watson et al, 2018; Anonimous, 2020), is to obtain homozygous lines from the segregating materials after hybridization. Instead, the speed breeding method, this process can be completed in one year. Thereby, the period from hybridization to variety registration can be shortened remarkably. However, since limitted space used for speed breeding, it is not possible to advance all the variation in the segregating populations in the growth chambers or greenhouses. In this context, the technique of Single Seed Descent (SSD) can be used to preserve and advence of the initial variation. In the SSD, one seed from each plant is advanced to the next generation (Chahal and Gosal, 2002, Watson et all, 2018). F6 pure lines can be obtained by repeating the same process in each generation, preserving the initial variation.

Shortening the breeding time is crutial not only in terms of generation accelerating but also genetic research, tissue culture studies, mapping populations, seed reproduction, marker-based selection, characterization, backcross, and a tremendous advantage in terms of developing varieties or genitors that are resistant to biotic and abiotic stresses (Christophera et al., 2015; Yorgancılar et al., 2015; Alahmad et al., 2018; Salantur A., 2018; Watson et al, 2018 and Chaudhary et al., 2020).

Under normal circumstances, hybridization studies can be completed once a year while it can be accomplished 2-3 times under greenhouse circumstances in a year. Backcrosses may be required 5-6 times to transfer rust resistance, bunt resistant, hessian fly resistance and some other characters (Poehlman, 1987). In such a situation, while 5-6 years are required in classical breeding, these studies can be completed in 1-2 years with the speed breeding method. The situation is identical for the studies performed to bring different characteristics together. The speed breeding method is advantageous to complete the studies to collect different genes on a variety by using hybridization or biotechnological techniques in fewer period.

Biotic and abiotic stresses are the most considerable factors limiting quality and yield. For this reason, it has great importance to develop varieties that are tolerant or resistant to biotic (rust diseases, fusarium, powdery mildew, septoria, bunt, and smut) and abiotic (drought, heat, cold damage, salinity, sprouting) stresses. Studies to be enforced for this objective can be carried out more easily and in a shorter time with the speed breeding method, regardless of time or environmental factors (Christophera et al., 2015). The speed breeding method provides an advantage, especially in terms of test studies for grown plant resistance.

Resolution can be obtained in a shorter time with the speed breeding method against the difficulty that occurs on a local or global scale. From this point of view, rapid measures and defense mechanisms can be established against possible problems such as the Ug99 stem rust race (Akan et al., 2008) that may threaten food supply and security, with the speed breeding method, especially in a global scale. As a result, the impact of likely economic losses can be reduced.

Landraces and wild species are a rich source of genes that resources are used in breeding programs. However, these genetic resources need to be protected (Karaman, 2020). Genetic material losses may occur due to problems caused by environmental factors (frost damage, water logging, sprouting, etc.), especially during studies conducted under natural conditions (Karaman et al., 2020). It provides a safe working opportunity for the reproduction of the seeds of genetic resources or genetic studies conducted on such materials.

A generation can be produced once a year under natural circumstances. In particular, about 5-6 years and a large area are needed to obtain the advenced lines. Aditionally, tillage, planting preparation, sowing, maintenance operations, harvesting, and threshing processes are required annually. Besides, labor and mechanization infrastructure are not only the necessities for these activities to be enforced but also combining all these components is both costly and difficult. In the speed breeding method, a growing cycle of spring wheat (T. aestivum L.) can be completed in about 60 days and the 6 generations and all processes can be completed in just one year. Since reduced labor is needed, the speed breeding method is an inexpensive technique compared to other using methods in classical breeding.

SPEED BREEDING RESEARCHES IN BLACKSEA ARI

The speed breeding method has been applied in order to accelerate generation in the wheat breeding program carried out in the Blacksea Agricultural Research Institute. For this purpose, the Speed breeding unit was built in 2019.

Sandwich panels (rock wool,10 cm) are used in the construction of the plant growing unit (70 m²) (Fig.2a). LED lamps (Fig.2e) are used for the lighting system. Inverter split air conditioner (24000 BTU) (Fig.2c and d) was used for heating and cooling for temperature adjustments. Table type workbenches are constructed to place viols. The benches are made of 6 cm deep sheet metal plates in the form of a pool for automatic irrigation (Fig.2b).


b

c d e

Figure.2: Main components of the growth chamber. **a)** Growth chamber, **b)** Trays and viols, **c)** Inverter split air conditioner, **d)** Remote, **e)** LED lamps.

The speed breeding method have started to be applied in 2020. In practice, the protocol specified by Watson et al. (2018) was used. Accordingly, 22 hours / 22 ºC light period, 2 hours / 17 ºC dark period was created and the humidity level was applied as 70%. The spring bread wheat variety Altındane was used in the first test study.

The study carried out for testing purposes. Seeds were germinated at room temperature by soaking them with sterile water in petri dishes with filter paper. Germinated seeds were planted in 28-cell (51x32x7 cm) viols filled with potting soil. Rapidly emergence plants, which occur quickly output, reached the 2-leaf stage in a week. Heading occurred on the 28th day, while flowering occurred on the 35th day. Two weeks after flowering, the spike was harvested by collecting with scissors on the 49th day. After the harvest, the spikes were dried at 37 °C in oven for 4 days.

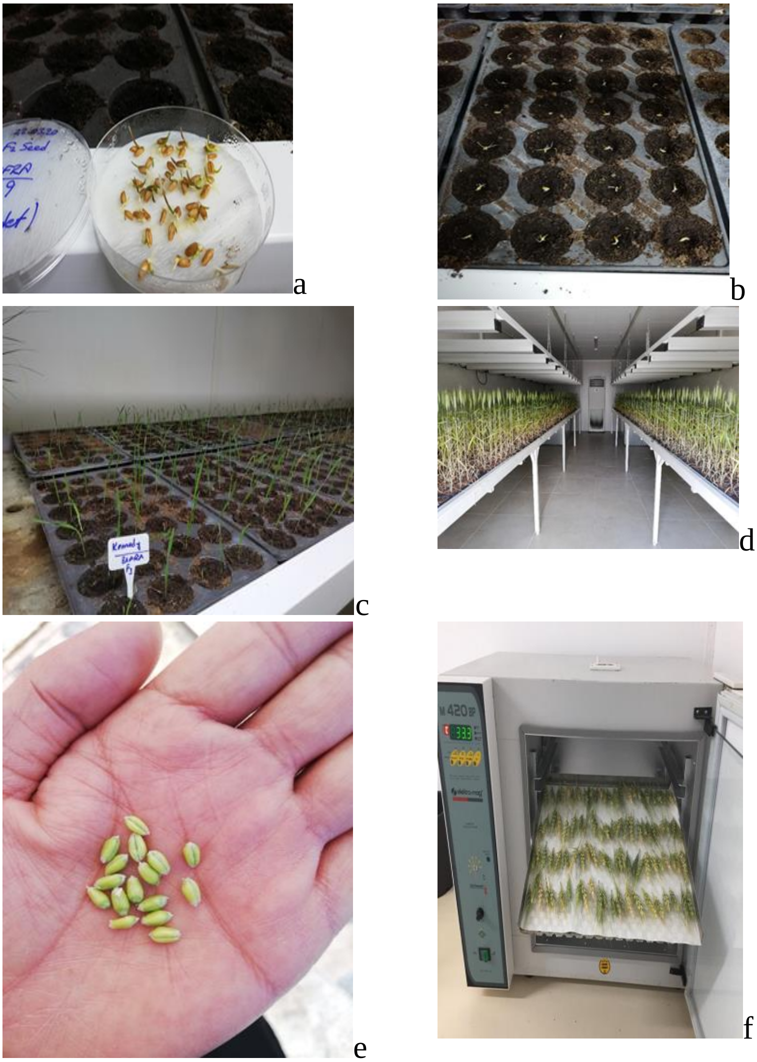
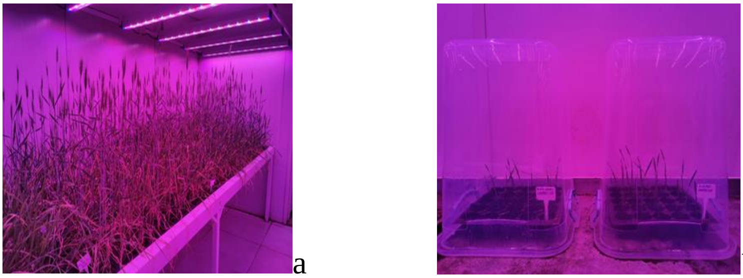


Figure.3: The photos from Speed Breeding Researches in Blacksea ARI. **a)** germination, **b)** sowing, **c)** a week old plants, **d)** the plants on 49th day, **e)** seeds from a spike on 49th day, **f)**

Germination test was carried out on seeds obtained from dried spikes. For this purpose, the seeds were placed in petri dishes with filter paper and they are soaked with sterile water containing 0.5 ppm gibberellic acid. Petri dishes were kept for 2 days at 4 °C for 48 hours for pre-chilling and then they are germinated under room conditions.

After the test work, the hybrid combinations were planted to accelerate the generation. With this method, F6 seeds belonging to hybrid combinations were obtained at the end of 2020. As a result, six harvests were done in 12 months. The single-seed descent method was used in accelerating the generation process. In this method, 300 plants are calculated for each population.

In addition to the accelerating generation studies, it is planned to carry out further disease studies. For this purpose, a preliminary study against rust diseases and a research study on resistance resources against fusarium head blight has been initiated.



a b

Figure.4: The photos from Speed Breeding Researches in Blacksea ARI. **a)** a cross population, **b)** testing for resistance to rust diseases.

CONCLUSION

Agricultural production should be increased in balanced with the increase in the world population for the sustainability of food supply and security. Therefore, new and effective approaches are needed in plant breeding.

Biotechnological methods have been developed with the increase of technological possibilities in recent years. Effective genetic studies have been started thanks to these methods. With the help of better understanding genes, varieties with higher genetic potential have been developed in terms of yield and quality. At the same time, stability in agricultural production has been achieved by developing varieties that are tolerant to biotic and abiotic stress conditions.

The competition against time has gained importance in the new world. Time-saving has become important in order to resist the world population growth rate and to solve the problems encountered in agricultural production in a shorter time. From this point of view, the importance of the speed breeding method can understand better. The speed breeding method can increase the effectiveness of breeding programs and provide a significant advantage to human beings against time.

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CHAPTER 5

NET PHOTOSYNTHESİS OF WHEAT UNDER ABİOTİC STRESS: A REVİEW

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INTRODUCTION

Wheat is a very important food for the world but yield increase rates by breeding is in a very slowed trend. Improved photosynthesis and radiation use efficiency in cereals are new targets to boost yields in crops. But abiotic stress factors poses a great challenge to success. Drought, salinity, nutrient use efficiency, atmospheric changes are major abiotic factors preventing photosynthetic improvements.

Here in this review, abiotic stress-photsynthesis relation is analysed briefly to highlight the main paths to be followed by new researchers on this under explored research area for wheat improvements not just by crop management but also by breeding efforts. Selected articles given here below are directly related to the subject of “net photosynthesis in wheat”. General comments are given in conclusions part of this study.

Wheat is the most important food crop in the World (Morris & Rose, 1996; Uçar, 2020). Its success depends partly on its adaptability and high yield potential (Shewry, 2009). The genetic potential of the harvest index (HI) and grain number were the main target in the green revolution by cereal breeders (Furbank et al., 2015). Adoption of “green revolution” “dwarfing genes” into wheat looks like exploited; improvements in biomass and radiation use efficiency are now targets to be well explored for cereals (Furbank et al., 2020).

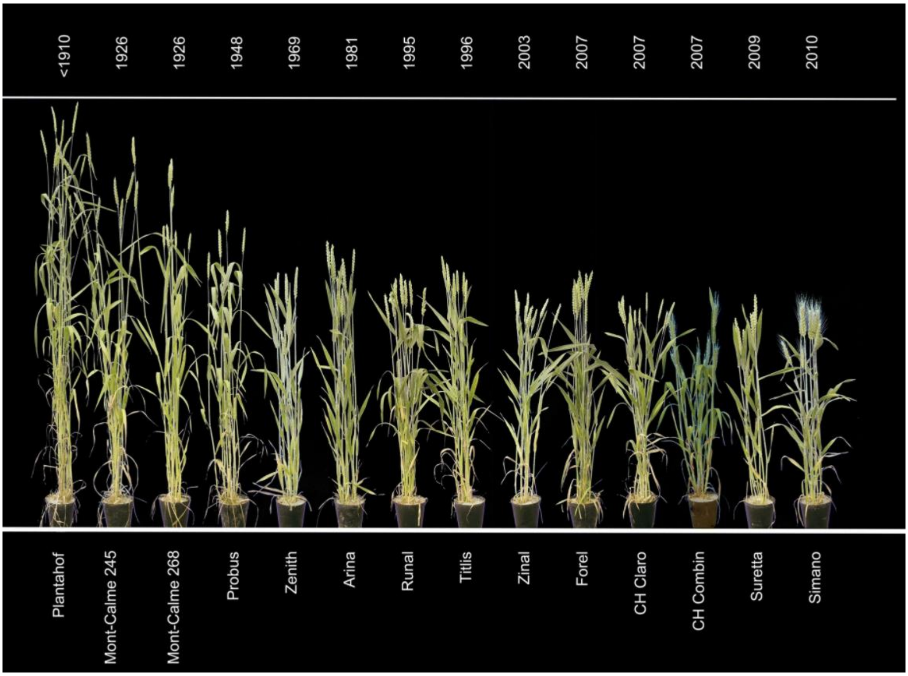

Figure 1. 100 years of Swiss bread wheat breeding (Friedli et al., 2019)

Future genetic progress in wheat grain yield will probably depend on above ground biomass increases (Gaju et al., 2016). In the last decade, effort were focused on identifying the targets to improve photosynthetic performance, light interception efficiency, harvesting, improving photosynthetic capacity, energy utilisation and efficiency in photosynthetic carbon metabolism in wheat (Furbank et al., 2015). Photosynthesis is next major trait for wheat yield improvement as breeders reached the plateau for HI. Genetic diversity at photosynthesis is now possible to be discovered by using advanced and low-cost techniques. Photosynthetic traits are highly heritable and there exist significant variation in germplasms for these traits. This presents opportunities for breeding effords for improved photosynthesis and radiation use efficiency in cereals to boost yields (Furbank et al., 2020).

Global warming impacts agricultural productivity and poses a great challenge to the global agriculture. Recent climate change models predict severe losses in crop production worldwide (Abhinandan et al., 2018). Under natural conditions, crops experience high leaf temperatures that reduce growth, reproduction and photosynthesis which effects crop yields dramatically (Almalki, 2014).

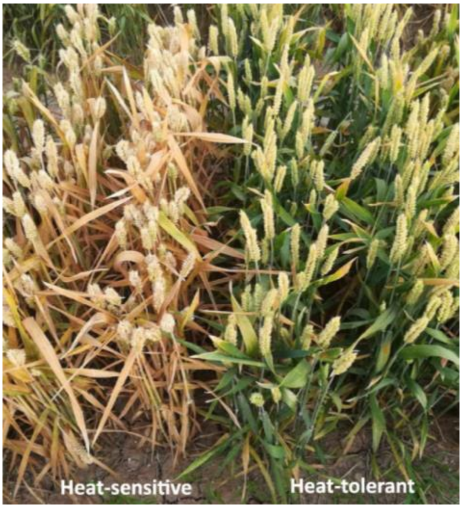

Figure 2. Heat-sensitive and heat-tolerant genotypes after heat stress under field conditions (Ni et al., 2018).

Drought has the highest share (26%) in stress factors in usable agricultural areas in the world (Bicer & Yilmaz, 2013). So drought is a main environmental stressor reducing wheat production. Due to the fast growth of the world's population, a sufficient amount of food is needed in terms of calories and other nutrients (Long et al. 2015; Ali et al. 2019). Plants must be resistant to abiotic stress factors in order to improve the nutrition quality of the products. As a main nutrient, nitrogen availability significantly affects adaptation of plants to abiotic stress (Gao et al., 2019). As a result of global change, under elevated CO_2, it is expected for wheat that net photosynthesis may rise which may alter the progress of senescence sourcing from unbalance of carbohydrates and nitrogen (Zhu et al., 2009). Another abiotic stress, soil salinity is also one of the most important abiotic stresses limiting plant growth and productivity. The breeding of salt-tolerant wheat cultivars has substantially relieved the adverse effects of salt stress (Oljira et al., 2020).

Kaul (1974) was grown six wheat cultivars in the field with continuously progressing water deficits ended by extreme levels at the end of the season. The relative yield performance of five of six bread wheat cultivars were predictable from the potential net photosynthesis of their flag leaves.

Iqbal & Wright, (1998) applied water deficit in pots to spring wheat (*Triticum aestivum*) and two different C3 annual weed species (*Chenopodium albüm and Phalaris minor*) in pure stands of wheat and in mixtures of weed species. Water deficit decreased net photosynthesis significantly at all species mainly due to decreases in stomatal conductance. In wheat and C. album, net photosynthesis recovered following re-watering. Early water deficit increased the weed's relative competitive ability where a late stage deficit increased the relative competitive ability of the wheat.

Malik & Wright, (1997) conducted a pot experiment with six drought resistant and six drought susceptible wheat genotypes. Net photosynthesis decreased under drought mainly by non stomatal factors. Net photosynthesis under drought were different for genotypes with same stomatal conductance. Measurement of net photosynthesis and water-use-efficiency found suitable to be used as breeding criteria for drought resistance.

Water and nitrogen stress are the main constraints limiting yield in wheat *(Triticum turgidum L.* var. *durum)* (Lopes & Araus, 2006). The physiological mechanism of response of photosynthesis to low nitrogen can help to optimize nitrogen management and to breed nitrogen efficient cultivars (Gao et al., 2018). Vertical canopy gradients of nitrogen in leaves has been seen as an adaptation to the light gradient that helps to increase canopy photosynthesis to maximum level (Dreccer et al., 2000).

Stomatal conductance, leaf nitrogen concentration and assimilate demand of grains affect the CO_2 exchange rate of leaf of winter wheat during grain fill (Frederick, 1997). The reaction of wheat to increased CO_2 concentration is likely to be depend on nitrogen supply (Li et al., 2019).

Radiation use efficiency (RUE) is useful measurement for estimating accumulation of carbon in terrestrial plants communities. Total 27 canopies of two different varieties of winter wheat and five different varieties of spring wheat were analysed by Choudhury (2000). Strong linear relationships were found between the Radiation use efficiency and incident radiation. Temperature was ,an important factor for determining RUE under predominantly cloudy conditions.

Net photosynthesis, point for CO_2 compensation, and ribulose-1,5-bisphosphate carboxylase (RuBPCase) activity were determined in the flag leaves of one durum wheat and one bread wheat from anthesis to senescence by Massachi et al., (1986). Net photosynthesis was not different for two cultivars. A linear relation was found between net photosynthesis and RuBPCase. Similar carboxylation efficiencies were observed at two cultivars. Dark respiration, measured as O_2 uptake by leaf slices, showed little change through maturation and senescence of the leaves. In mature leaves, this respiration was significantly higher in the soft wheat cultivar, while in senescent leaves, this difference disappeared.

Increased activation of Rubisco by “Rubisco activase” can potentially enhance CO_2 assimilation and photosynthetic efficiency in plants (Saeed et al., 2016). Expression of “Rubisco activase” at heading (Z55), anthesis (Z67) and grain-filling (Z73) stages were investigated through qRT-PCR analyses at 59 bread wheat genotypes and their effects on net photosynthesis rate (Pn), biomass/plant (BMPP) and grain yield/plant (GYPP) explored. Similar expression patterns were observed for the three copies at the three growth stages with highest expression at grain-filling stage. Genotypes with higher “Rubisco activase” expression also showed higher values of photosynthesis rate, biomass per plant and grain yield per plant. Concluded that manipulating “Rubisco activase” expression may efficiently improve photosynthesis rate, biomass per plant and grain yield per plant in bread wheat.

Enhancing Rubisco efficiency via genetic modifications in cereal crops is importance to improve photosynthesis. Rubisco specific activity reflects photosynthetic rate at atmospheric CO_2 levels. However, escaping from an unbalance between Rubisco and other photosynthetic limiting factors is a priority (Makino & Ishida, 2008).

In their study, Oljira et al., (2020) fungal isolate *Trichoderma afroharzianum*, which produce indole-3-acetic acid (IAA) under salt stress (200 mM). The isolate seed coated on salt-sensitive and salt-tolerant wheat cultivars. Salt stress (S), cultivar (C), and microbial treatment (M) significantly affected water use effici. Treatments enhanced net photosynthesis, water use efficiency and biomass production. Oljira et al., 2020). Study illustrated that Trichoderma enhance the growth of wheat under salt stress and can be used as plant biostimulant.

Sensitivity of net photosynthesis to ozone and the reactive oxygen species (ROS) scavenging system in wheat *(Triticum aestivum)* were investigated by Inada et al., (2012). Net photosynthetic rate of the flag leaf of variety Norin 61 was not significantly reduced by exposure to O_3. But net photosynthetic rate of variety Shirogane-komugi was significantly reduced by the exposure to O_3 during the anthesis and early grain-filling stages. Sensitivity of net photosynthesis of flag leaf to O_3 was higher in Shirogane-komugi than in Norin 61. This difference was mainly due to O_3 detoxification ability of ROS by the activity of

ROS scavenging enzymes (catalase and monodehydroascorbate reductase).

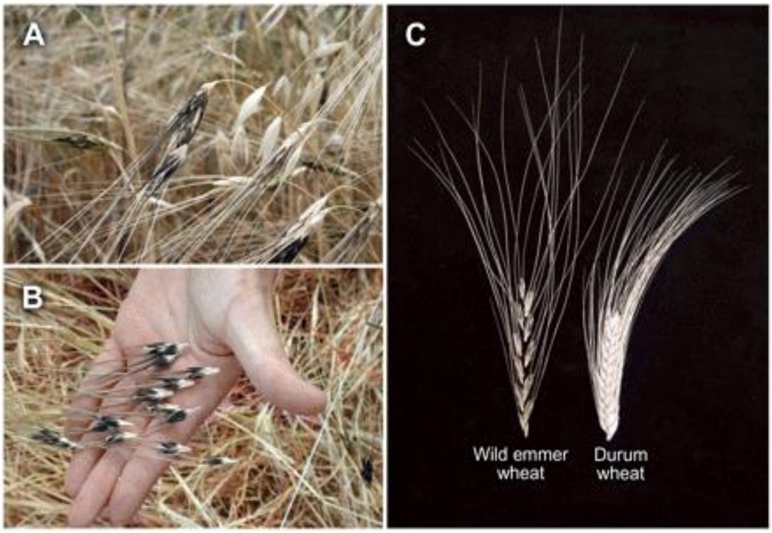

Figure 3. (A) Wild emmer wheat (*Triticum turgidum* ssp. *dicoccoides*) (B) Spikelets of wild emmer wheat collected from the soil surface. (C) Brittle rachis spike of wild emmer wheat and non-brittle spike of domesticated durum wheat (Peleg et al., 2011).

Air in Earth's atmosphere is made up of approximately 78% nitrogen and 21% O_2. When the leaves put in an O_2-free atmosphere, stomata of wheat *(Triticum aestivum* L.*)*and barley *(Hordeum vulgare* L.*)* leaves were not able to open in light, close in dark or respond to CO_2 concentration changes in the atmosphere in either light or dark in the study of Akita & Moss, (1973). In contrast, responses were found in atmospheres including 1,5% O_2. So, oxygen is necessary for opening and closing of stomata of barley and wheat.

The net CO_2 exchange rate of flag-leaf blades of 20 oat (*Avena* spp.) genotypes was measured by Criswell & Shibles, (1971). Net photosynthetic rate and rate of CO_2 efflux into CO_2-free air in light differed significantly among genotypes. The CO_2 compensation point was not related to net photosynthetic rate. A positive correlation between net photosynthesis and CO_2 efflux was found. Genotypes showing high CO_2 efflux rates were showing a lower resistance to CO_2 diffusion between leaf respiratory sites and the external atmosphere. Differences in diffusion resistances, particularly the residual or mesophyll resistance, explained the differences in net photosynthesis. Mean genotypic net photosynthetic rates were correlated with mean specific leaf dry weights (g dry weight / leaf area). Residual resistance values were negatively correlated with mean specific leaf dry weight values.

CONCLUSIONS

When we evaluated the studies on net photosynthesis, we can realise that net photosynthesis has a high capacity to improve but it is limited by multiple abiotic stress factors. Performance of wheat cultivars can be predicted by net photosynthetic potential in flag leaves. Also a linear relation was observed by researchers, between RuBPCase and net photosynthesis. Manipulating “Rubisco activase” expression may efficiently improve photosynthesis rate, biomass per plant and grain yield per plant in bread wheat. A major global problem, water deficit is significantly decreasing net photosynthesis mainly due to decreases in stomatal conductance. Measurement of net photosynthesis and water-use-efficiency found suitable to be used as breeding criteria for drought resistance. Radiation use efficiency (RUE) is useful measurement for estimating carbon accumulation in terrestrial plants communities. Biostimulants of biological growth enhancers like Trichoderma, which produce "indole 3 acetic acid" (IAA) under salt stress, may effect net photosynthesis and as a result, improve the growth of wheat and can be used as plant biostimulant.

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CHAPTER 6

DETERMINATION AND EVALUATION OF QUALITY PARAMETERS IN COOL CLIMATE CEREALS

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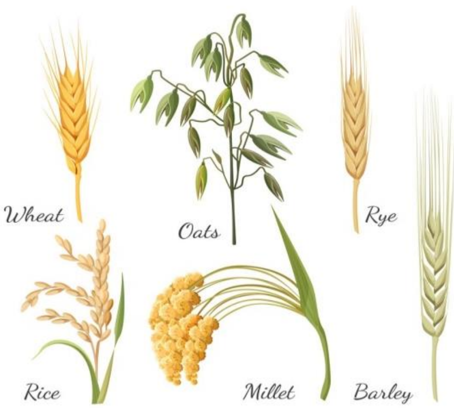
INTRODUCTION

One of the most important problems that await so many people is the inadequate, unbalanced and low quality nutrition. It is possible for people to carry out their daily activities by meeting the amount of nutrients needed by metabolism. Cereals are an important source of nutrition and lack of micronutrients affects the health of all living things (Duz at al., 2017). Cereals are an important source of carbohydrate and protein in meeting this daily need. Therefore, grains are among the priority foods in nutrition.

Cool climate cereals can be consumed directly through various processes and are raw materials or auxiliary materials for many industrial products (bread, pasta, biscuit, etc.). For this reason, cool climate cereals are a strategic product. Wheat, barley, oats, rye and triticale have an important place in human and animal nutrition among the cool climate cereals. Barley is used as first degree animal feed and as a raw material in brewing. Oats have an important place in human and animal nutrition. This makes the cool climate grain products, especially wheat, strategic products. Wheat> barley> rye> oat> triticale is grown in the vast majority of the lands reserved for the cultivation of cereals in our country, depending on the size of the cultivation area (Anonymous, 2016).



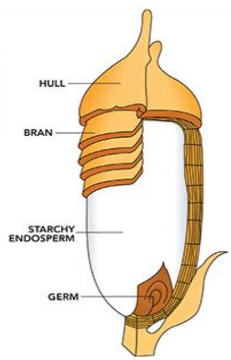


Fig.1. Grains (Cool Climate Cereals) (Anonymous, 2021a) **Fig. 2.** Parts of Grain (Anonymous, 2021b)

-Wheat: (*Triticum monococcum*, 2n=14; *Triticum durum*, 2n=28; *Triticum aestivum*, 2n=42; *Triticum compactum*, 2n=42)

Wheat is a cool climate grain that is mostly consumed as human food, processed in different ways (flour, cake, couscous, pasta, bulgur, etc.) (Karaman and Akın, 2020). However, wheat production has not yet been achieved in the world at a level that will meet the food needs of people and eliminate nutritional problems (Karaman, 2020). It can be classified according to planting time, color, structural features, purpose of use, etc.

-Barley: (*Hordeum vulgare distichon*, 2n=14; *Hordeum vulgare hexastichon*, 2n=14)

Barley is an important cereal plant that is generally used as malt and feed. World production in cereals, barley is located after wheat rice and corn. In our country, 90% of the consumption is used as animal feed, the remaining part is used as malt in the beer industry and food industry(Anonymous, 2017a).

-Rye: (*Secale cereale*, 2n=14; *Secale cereale*, 2n= 28)

Rye is the most cold-resistant grain and can yield even on soils that are not suitable for growing other grains. Carbohydrate, protein, potassium and B vitamins are important quantitatively in the composition of rye, which is mostly considered as bread flour and animal feed.

-Oat: (*Avena sativa*, 2n=42; *Avena byzantina*, 2n=42)

Oats are an agricultural plant grown for its abundant starchy grains. This grain, which is mostly used as animal feed, also used in human nutrition. Oat also contains plenty of starch and protein, vitamins and minerals. Since the dough prepared from oat flour does not rise like wheat flour, it is not used in bread making. Oats are also important for a healthy diet.

-Triticale: (Hekzaploid triticale AABBRR, 2n= 42; *Triticum durum* X *Secale cereale*) (Oktaploid triticale AABBDDRR, 2n= 56; *Triticum aestivum* X *Secale cereale),* (Tritordeum, *Triticum durum* X *Hordeum chilense*, 2n= 42)

Triticale is a type of cereal produced by the hybridization of wheat and rye. Triticale aims to obtain the ability of rye to grow in difficult and unproductive soils with the bread feature of wheat. It is not suitable for use in bread making alone.70% wheat + 30% triticale blends are suitable for bread making (Anonymous, 2017a).

QUALITY CRITERIA IN COOL CLIMATE GRAINS

Quality (Qualites) comes from the Latin word "quails" which means "how it is formed". In essence, the word quality is intended to reveal what product and service it is used for, what it really is.

The following definitions are also used to explain the concept of quality.

- Quality is all of the characteristics that reveal the ability of a good or service to meet a specific requirement (American Association for Quality Control).

- Quality is the degree to which a service or product conforms to its demands (European Quality Control Organization).

- Quality is the degree to which a product complies with the requirements. The desired properties of a product depend on the place where the product will be used. In this respect, quality control is not the control of superior products; It aims to control products with desired properties (Anonymous, 2008).

Quality criteria and evaluation of parameters in cool climate cereals, classified as:

Physical, Chemical and Analytical (Technological and Rheological) Quality Criteria. Several methods of different associations and organizations are available (e.g. Association of the Official Analytical Chemists (AOAC), American Oil Chemists Society (AOCS), International Association for Cereal Science and Technology (ICC), American Association of Cereal Chemists (AACC), International Standard Organization (ISO))

Sampling

While sampling flour, general rules must be followed, as in sampling from wheat. When taking samples from the sack, the first samples should be taken from the upper, middle and lower parts of the sack with sack probes. The aggregate sample should be thoroughly mixed.

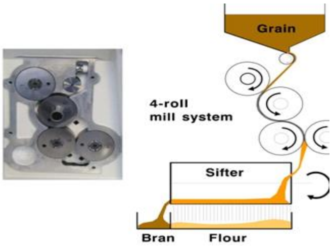


Fig. 2 Milling Sistem for Sampling (Anonymous, 2012)

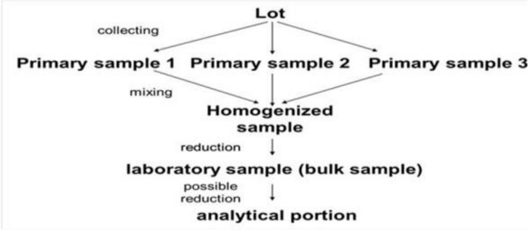


Fig. 3 Sampling Scheme (Sipos,2013)

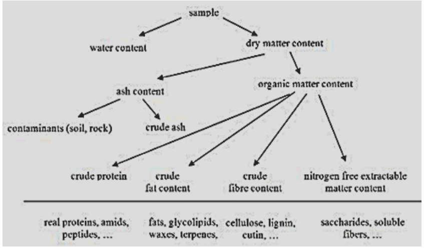


Fig.4 Composition of a Food or Feed Sample (Sipos, 2013)

Table 1. General Directorate of TMO Product Technology and Laboratory Branch Directorate List of Experiment Methods. f-038/rev.00/-publicationdate: (08.04.2019)(AACC, 2000; ICC, 2003; AOAC, 2000;ISO, 2000; TSE) (Anonymous, 2021c)

Tested Product	Analysis Name	Method Name
Cereal and Cereal Products	Moisture Determination	TSE EN ISO 712; ICC 110/1 AACC 44-19.01.
Cereal and Cereal Products	Ash Determination	ISO 2171; AACC Method 08-21.01.;ICC-104/1
Cereals	Hectoliter Weight Determination	TSE EN ISO 7971–3
Wheat	Hardness Test- Near-Infrared Reflectance	AACC Method 39-70.02.
Cereal and Cereal Products	Protein Determination Kjeldahl Method	AOAC 2001.11;ICC-105-2; ISO 20483
Wheat flour	Determination of Sedimentation Index - Zeleny Test	TSE EN ISO 5529;105/2,ICC
Wheat flour	Determination of Damaged Starch	ICC 172; ISO 17715
Flour and Cereal grains	Determination of Falling Number	TSE EN ISO 3093;ICC 107/1
Wheat and Flour	Wet Gluten Determination	ISO 21415-2;AACC 38-12.02.
Wheat and Flour	Gluten Index Determination	ISO 21415-2; No. 155, ICC
Wheat and Flour	Dry Gluten Determination	ISO 21415-4; AACC 38-12.02
Wheat flour	Alveograph Experiment	ISO 27971;AACC, 54-30.02.
Wheat flour	Farinograph Experiment	AACC method 54-21;ICC standard 115/1;ISO 5530-1
Wheat flour	Extensograph Experiment	ISO 5530-2;AACC method 54-10; ICC standard 114/1
Wheat flour	Determination of Suspended (Modified) Sedimentation Index	"DM-016"(Modified by ISO 5529)
Wheat and Barley	NIR Method Protein and Moisture Determination	TS EN 15948,; AACC Method 39-10.01
Wheat flour	Acidity Determination	TS 4500; AACC Method 02-04.02
Cereals	Aflatoxin B1 and Total Aflatoxin (B1 + B2 + G1 + G2) HPLC Method	ISO 16050;AACC,45-16.01
Wheat, Barley, Rye, Oat, Triticale	Substances Other Than Intact Cereals, Vitreous Grain Ratio Test (Durum Wheat)	TS 2974;TS 4078;TS 3267 TS 3200;TS 13138; ICC-129
Wheat	Hardness	AACC 55-30.01;AACC3970.02
Barley, Oats,Rye	β-Glucan (mixed linkage), colorimetric method β-Glucan Content of Barley and Oats -- Rapid Enzymatic Procedure	AOAC Official method 995.16; McCleary and Mugford, (1997). ;AACC Method 32-23.01;ICC-166
Wheat Flour	Amylograph Test	ICC standard 169;ISO 7973;AACC , 22-12.01
Cereals	Mixolab Test, in Wheat Flour and Whole Wheat Meal by Mixolab	Standard Method ICC N°173; AACC Method 54-60.01.
Durum wheat flour, semolina and pasta	The amount of yellow color	ICC Standard Method 152; AACC Method 14-50.01; (CIE 1986),AACC 14-22.01
Durum Wheat Flour	Sedimentation Test for Durum Wheat(SDS), Sedimantasyon indexi	AACC Method 57-70.01.; ICC-151; TS EN ISO 5529
Cereals	Total Dietary Fibre	ICC- 156;AACC 32-07.01.
Cereals	Determination of Minerals by ICP-OES	AACC Method 40-75.01.
Cereals	Vitamins	ELİSA, HPLC,AOAC,EN/ISO
Cereals	Anioxidant and Phenolic substances	Yu at. Al,(2002),;Huang at al.(2005)

QUALITY AND EVALUATION OF WHEAT PHYSICAL QUALITY CRITERIA

-Hectoliter Weight: It is the measure of one hundred liters of wheat in kg. The size of the grain, its shape, surface roughness, humidity, the degree of exposure to wheat pests and the presence of inputs such as non-wheat garbage, stalk etc. in the incoming pile affect the hectoliter. The higher value; It is expected that the higher yield of flour with the same ash value to be obtained from that wheat (Anonymous, 2017a).

Fig. 5 Device of Hectoliter Weight

Fig.6 The Grobecker (wheat cutter tool)

-Vitreous Grain Ratio: It is defined as firm and hard structured, glassy looking grains that do not have floury spots in their outer appearance or crosssection (Anonymous, 2017a).

-Weight of Thousand Kernel : It is the weight of a thousand grains in grams that is specified as dry matter (Köksel et al. 2000). The moisture of the wheat does not affect the result. The fact that a thousand grain weight is high means that the percentage of endosperm in the fruit is related to flour yield is high (Pehlivan and Unver, 2017).

-Grain Hardness: Wheat is basically categorized as soft, hard and durum. The endosperm structure of wheat has an important place in terms of technological quality criteria. Hardness, one of the physical properties of the endosperm, is closely related to starch damage, particle size, semolina and flour size distribution and milling score during milling process (Hrušková and Svec, 2009).

Table 2.TMO, Minimum Quality Criteria to be Applied in Grain Purchase from 2020 and European Community standard for grains in intervention program (Delwiche, 2010; Anonymous, 2020)

	Durum Wheat	Common Wheat	Barley
A. Maximum moisture content	14,5%	14,5%	% 14,5%
B. Maximum percentage of matter which is not basic cereal of unimpaired quality:	12 %	12%	12 %
1. Broken grain**(1+2+3+4+5+6)**	6%	5%	5%
2. Impurities consisting of grains **(a+b+c+d+e)**	5%	7%	12%
(a) shriveled grains			
b) Other cereals	3%		5%
c) Grain damaged by pest	It is evaluated within the defective grain		
(d) Grain in wich the germ is discolored		Up to% 8‘e is not taken consideration	
(e) grains overheated during drying	0,5%	0,5%	3%
3. Sun and Chemical Destroyed Grains	It is evaluated within the defective grain		-
-Mottled grains and/or grains affected with fusariosis of which:	5%		
4. - grains affected with fusariosis	1,5%		-
5- Germinated, sprouted grains	4%	4%	6%
6- Miscellaneous impurities (Schwarzbesatz) of which (a+b+c+d+e+f+g)	3%	3%	3%
a) extraneous seeds:	0.1%	0.1%	0.1%
-noxious			
-others			
b)Damaged grains			-
- grains damaged by spontaneous heating or too extreme heating during drying	0.05%	0.05%	
-Spread / Wheat Rasp	0,06%	0,06%	
-Barley Rasp			%0,4%
(c) extraneous matter			
d) Husk			
(e) ergot	0,05%	0,05%	
(f) decayed grains			
(g) dead insects and fragments of insects			
C. Maximum percentage of wholly or partially piebald grains	27%		
D. Hectoliter kg / hl (min.)	78	73	62
E. Protein (Nx5,7) (min.)	11,5%	11%	
G. Hagberg falling number (seconds)	220	220	
H. Minimum Zeleny index (ml)	-	22	-
Zeleny (Sedimantation) değeri (ml) (min.)			
I.Yellow pigment content, at least, mg/kg**	5.0-3.5		
	3.5		

Table 3. Hardness Scale for Wheat (Hrušková and Svec, 2009)

Category	PSI (%)	NIR
Extra hard	lower than 7	higher than 84
Very hard	8–11	73–84
Hard	13–16	61–72
Medium hard	17–20	49–60
Medium soft	21–25	37–48
Soft	26–30	25–36
Very soft	31–35	13–24
Extra soft	higher than 35	lower than 12

CHEMICAL QUALITY CRITERIA

-Moisture Content: It is important both economically and in terms of storage. Mills want to increase their profit rates by purchasing wheat with low moisture content. Therefore, during the period until use, a smooth storage process will pass thanks to the low humidity. Moisture accelerates the deterioration of wheat as it increases enzyme activity and microbial activity (Anonymous, 2017a).

Table 4. Summary of Wheat Grade Factors of The Major Wheat Exporting Countries(Delwiche,2010)

Quality parameter	Argentina	Australia	Canada	European Union		France	United Kingdom	United States
Test Variety	Grade No. 1	APH2	No. 1 CWRS	Durum	Common Wheat	Class E Wheat	UKP Bread Wheat	US No. 1 HRS
Protein content	√	√	√	√	√	√	√	
Test weight	√	√	√	√	√	√	√	√
Falling number		√		√	√	√	√	
Moisture	√	√		√	√	√	√	√
Zeleny index				√	√	√		
Wet gluten	√					√	√	
Alveograph	√					√	√	
Farinograph	√					√		
Mixograph								
Ash	√						√	
Weight of 1000 kernels	√							
Odor		√	√				√	√
Hardness			√			√	√	
Baking test		√						
Milling		√						
Sampling								
Size before splitting	4 kg	> 3 L	900 g					1000 g
Size after splitting			>250 g					250 g, 15 g
First cleaned by: (1) Dockage tester			√					√
(2) Sieve	√						√	√
(3) Other		√						
Defects/Damage								
Heat damage	√	√	√	√	√		√	√
Shrunken and broken kernels	√		√	√	√		√	√
Sprouted	√	√	√	√	√	√	√	√

-Ash: It is a residue formed by inorganic oxides as a result of burning grains and vegetable substance. It is the amount of mineral matter which is calculated on dry matter. Ash is considered as a criterion in the diversification of flour according to the communiqué.

Table 5. Substances Found in Wheat Ash (g /100g) (Anonymous, 2021d)

Total ash	1,860	S	0,914	Ca	0,048
K	0,571	Mg	0,173	Na	0,009
P	0,428	Cl	0,055	Si	0,006

-Free Acidity: It gives information about the storage conditions of the wheat. The oils in the embryo of the wheat stored in bad conditions break down as a result of the reactions catalyzed by the lipase enzymes inherent in the grain and turn into free fatty acids. The high amount of free acidity gives information about the high level of all enzymatic activity in wheat due to poor storage conditions. Values, between 15-30 at the end of the harvest can reach up to 100 with bad storage (Anonymous, 2017a).

-Crude Fiber: The amount of crude fiber in grains ranges from 1 to 4%. It contains cellulose, hemicellulose and pentosans (Sipos, 2013)**.** Wheat grain cellulose substances vary between 2-2.7%. The amount is more in small or wrinkled grains. It adversely affects the flour yield. Just like ash, the amount of cellulose is a value that increases towards the outer part of the grain. It gives information about the addition rate of the from the flour obtained in the parts of the grain close to the bran (Anonymous, 2021d).

-Protein Content: Protein quantity and quality are the primary factors that play a major role in the formation of quality in wheat (Tekdal at al.2014). The protein content in cereals varies between 7 to 17%. This ratio varies depending on the species and variety. The amount of protein in wheat ranged between 10 and 16%. Wheats with high protein content are generally preferred. However, starch and related industries (sugar products, ethanol) and manufacturers such as biscuit products prefer low protein wheats because there is a negative correlation between starch and protein content. The proteins found in specific fractions of cereals have specific names. The albumin fraction of wheat is called leucosin. The globulin fraction is called edestin. The prolamine fraction is called gliadin and glutenins is called glutenin. (Sipos, 2013). The proteins that make up gluten are glutenin and gliadine. Globulin and albumin do not exist in the form of gluten or are present in very small amounts because they dissolve in salty water during dough making and cooking (Köksel et al., 2000).

ANALYTICAL (TECHNOLOGICAL AND RHEOLOGICAL) QUALITY CRITERIA

-Gluten Content: The determination of gluten content is due to its characteristic three-dimensional elastic, ductile network and its insolubility in water. Therefore, when flour is mixed with salt water, the salty water-soluble components (high amounts of mineral elements, lipits, fibers, carbohydrates, and salty water-soluble proteins) are washed away, only gluten and a very small amount of other components remains. Wet gluten is obtained by centrifuging the mass obtained. The amount of wet gluten content ranged between 14 to 35%. It is proportional to the amount of flour that is weighed. Dry gluten amount; dry gluten is obtained by drying wet gluten to 103 °C. Dry gluten content is approximately one third of wet gluten content.

-Gluten Index: Gluten index is the value found by proportioning the amount remaining on the sieve after centrifugation to wet gluten and multiplying it by one hundred. In wheat, it is desired to be between 60 and 90%.

Table 6. Evaluation of Flour Which Include Gluten Content (Anonymous, 2013)

Wet Gluten Amount (%)		Gluten Quality
Flour	**Crushed Flour**	
>35	>30	High
28-35	23-30	Good
20-27	15-22	Medium
<20	<15	Low

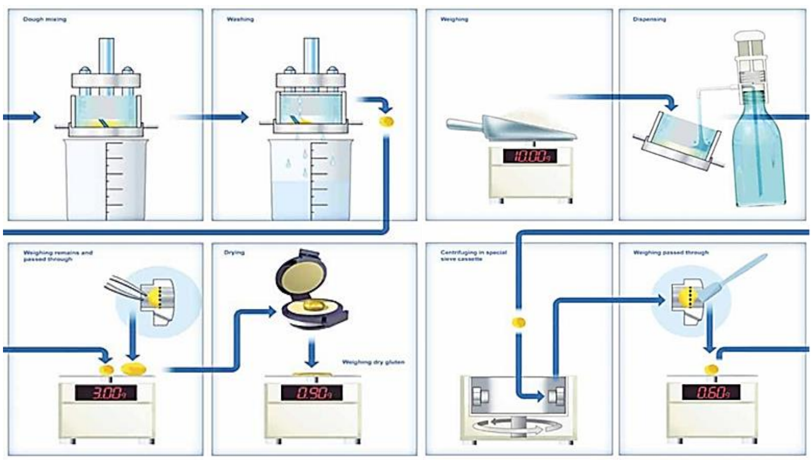


Fig. 7. Wet and Dry Gluten Procedure **Fig.8.** Gluten Index Pocedure (Anonymous, 2021e)

-Sedimentation Value: The sedimentation value is also one of the characteristic quality parameters of the flour protein. As a result of its interaction with lactic acid and isopropyl alcohol for a certain period of time, the read volume is evaluated as zeleny sedimentation. The higher volume means the higher protein ratio and the better protein properties (Anonymous,2017). The method used for durum wheats is SDS (Sodium Dodecyl Sulfate) technique. In addition, sedimentation index is accepted as an important quality evaluation criterion. It is determinated according to TS EN ISO 5529 method.

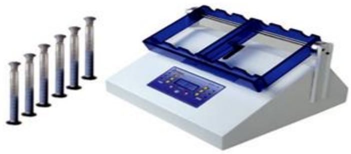


Fig. 9. Device of Sedimentation

Table 7. Evaluation of Flour According to Sedimentation Values

Sedimentation Value	Gluten Quality
36 ml and above	Very Good
Between 25 ml -36 ml	Good
Between 15 ml-24 ml	Medium
15 ml and below	Weak

-Delayed Sedimentation: It is the sedimentation value measured by waiting 1 hour after the normal sedimentation test is completed. If it is close to or higher than the sedimentation value, it is understood that the wheat is not exposed to the bug pest. If the value is less than the sedimentation value, it means that the sun's proteolytic enzymes have impaired the gluten structure on the face (Anonymous, 2017a).

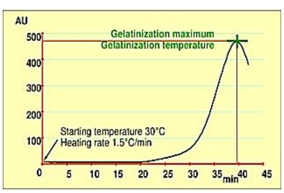
-Falling Number: It is the time in seconds until the dough prepared with flour and water is pasted in a hot water bath with the help of a mixer, and the mixer left in it reaches the bottom of the tube by gravity. If the enzymatic activity in the flour is high, the value is expected to be low. It is important in terms of the amount of gas that will form during the fermentation of the dough.

Table 8. Evaluation of Results

Falling Number (seconds)	Flour Amylase Activity
Less than 150	Extreme high
200-250	Normal
Higher than 300	Very low

Fig..10. Falling Number Device and Viscosimeter Tubes (Anonymous, 2013)

-Amylograph Test: The suspension of distilled water and flour is distilled into a rotating bowl, heated at a constant heating rate of 1.5 ^{o}C per minute. Depending on the viscosity of the suspension, the measuring sensor deflected, when the viscosity of the suspension reaching the bowl. The deflection is measured depending on the time and temperature of the viscosity.



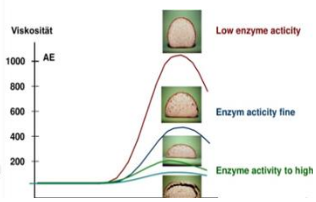


Fig. 11. Amylograph Test Curve (Anonymous, 2012) **Fig.12.** The Amylograph Device **Fig.13.** Amylase Activities

The graphical reading of the amylograph test is the initial temperature of gelatinization, the maximum viscosity temperature and the highest (BU, Brabender Unit) amylograph value. A value between 300 and 900 AE is required for standard baking use (Sipos, 2013).

-Yellow Color Content: The amount of yellow color pigment in the grain is very important for pasta, bulgur and semolina. Since the consumer prefers pasta with a bright yellow color, varieties with high semolina and yellowness value in durum wheat are especially preferred by the pasta industry (Pehlivan et al., 2008). There are more yellow color pigments in durum wheat than other grains. The amount of pigment in semolina varies between 4-8 ppm (Özkaya and Özkaya 1993). In another study, the amount of yellow pigment of durum wheats changed between 3.0 ppm and 6.9 ppm and these varieties were divided into medium quality (3.0-5.0 ppm) and good quality (> 5.0 ppm) according to the amount of yellow pigment they contain (Mohammed et al. 2012; Pehlivan and Unver, 2017). Durum wheat flour, semolina and pasta yellow pigment amount are determined according to ICC standard method 152 and AACC method 14-50.01. In both methods, the yellow color pigment found in durum wheat is extracted with various solvents and measured spectrophotometrically. Absorbance is reported as beta carotene at 435.8 nm wavelength. According to CIELAB 1986, L, a and b values are measured spectrophotometrically in durum wheat flour and semolina. L (brightness), a (redness and greenness) b (yellowness and blueness) are measured (Ficco at al., 2014).

RHEOLOGICAL PROPERTIES

The technological properties of wheat are determined by measuring the rheological properties of the dough. Many methods have been developed in this field, but alveograph and farinograph are the most widely used methods in the world. In addition, methods such as extensograph, amylograph, mixograph and glutopic provide information about the rheological properties of the dough.

-The Farinograph: It is used to determine the amount of water that should be added to the dough to be obtained from flour until it reaches a certain consistency. This value is of great economic importance. On the other hand, it is used to obtain graphical data of the resistance of the dough (Fig.13), which has reached the standard consistency, against the s-shaped pallet mixers. The more the dough obtained is close to the initial consistency over time, the more stable it can be said.Stability, water absorption, development time and softening degree are among the results of this analysis. It is somewhat difficult to add the water needed to reach 500 BU in the curve, so a small tolerance is allowed. The maximum resistance line should be within the 20 BU line from the 500 BU line (Sipos,13).

Table 9. Farinograph Evaluation of Results (Anonymous, 2012)

	Weak flour	Strong flour
Water absorption [%]	54 - 58	58 – 67
Dough development time [min]	< 2,5	2,5 – 14,0
Dough stability [min]	< 3,0	> 10
Degree of softening [FU]	> 80	< 80

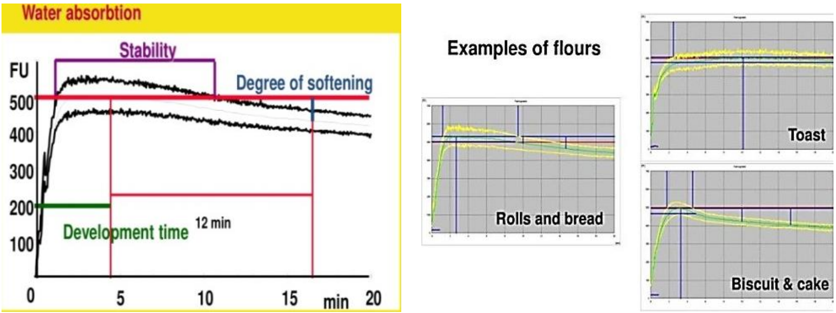


Fig.14. Farinograph Parameters According to AACC, ICC (Anonymous, 2012).

-**The Extensograph:** The dough of all flours to be analyzed in this device is obtained by adding water until it reaches a certain consistency level. The obtained dough is taken out of the cabinets where it is kept at certain time intervals and the strength it puts on the hook passed through the middle is measured. In this analysis;

- On tensile strength and resistance to elongation on extensibility

- Information about the energy of the dough can be obtained by using Extensograph (Anonymous, 2017).With this device, the resistances of the dough kept for 45, 90 and 135 minutes are graphed. The x-axis characterizes the time at which deformation begins and the elongation of the dough, and the y-axis determines the resistance of the dough against elongation. Other parameters determined are resistance to extension 5 cm, elongation, extensibility, maximum resistance and deformation.

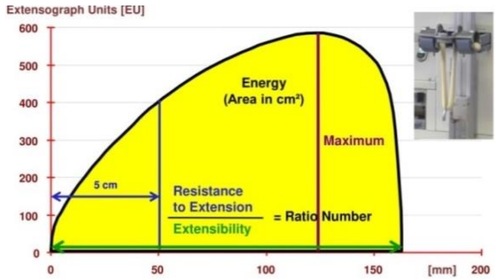


Fig.15. Extensograph Curve (Anonymous, 2012)

Table 10. Evaluation of Results

	Weak flour	Strong flour	Rigid, tough dough
Energy [cm²]	< 100	110-130	120-140
Resistance to Extension [EU]	< 300	400-600	> 600
Extensibility [cm]	100-130	130-160	< 120
Extension maximum[EU]	150-400	500-700	> 700
Ratio number	< 2,5	3,0-4,5	> 5,0

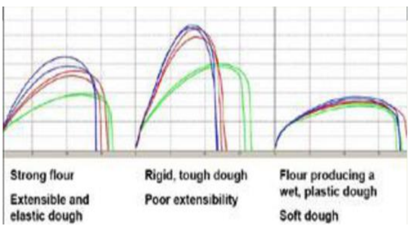
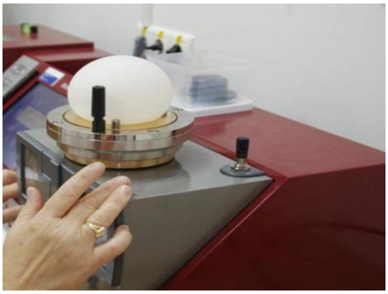


Fig.16. Evaluation of dough extensibility (Anonymous, 2012)

-The Alveograph: Five equal parts of the dough obtained from the flour to be analyzed are cut and kept for a certain period of time. At the end of the time, it is turned into a flat disc on the device and resists swelling until the dough is fixed. A balloon is created by giving air. The resistance shown by the balloon is graphically presented as a result of the dough; to be informed about, resistance, extensibility and energy (Anonymous, 2017a). With the device, time is measured on the x-axis and a graph is created on the y-axis that calculates the resistance of the dough bubble. The P value, which is the height of the curve, is expressed in mm. This characterizes the resistance of the dough. The P value is the maximum resistance that the dough can withstand. The L value characterizes the extensibility of the dough. The area under the curve is the energy value expressing the 10^{-4}J 'required for deformation of the dough (Sipos, 2013).



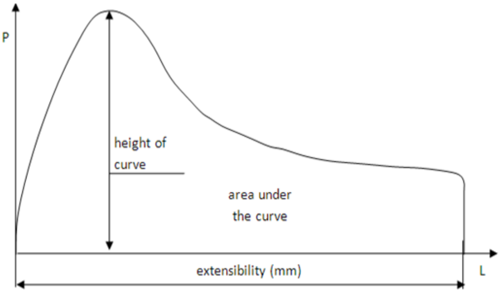


Fig.17. Alveograph Analysis (Anonymous, 2013) **Fig.18.**Alveograph Curve (Sipos, 2013)

Table 11. Evaluation of Flour According to W value in Alveogram (Anonymous, 2013)

W Value	Flour Force
0-50	Very weak
50-100	Weak
100-200	Medium
200-300	Medium strong
300-400	Strong
Greater than 400	Very strong

-Mixolab Test: It is a device used to measure the consistency of the dough. It measures both the starch and protein properties of the flour by increasing the applied temperature gradually depending on the time, and also provides information about the protein breakdown of the dough, development time, starch gelatinization, enzyme activity and gel strength (Dubat, 2010).

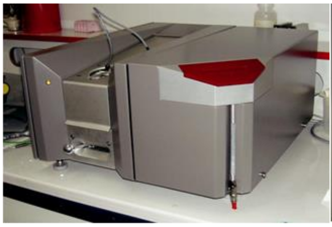
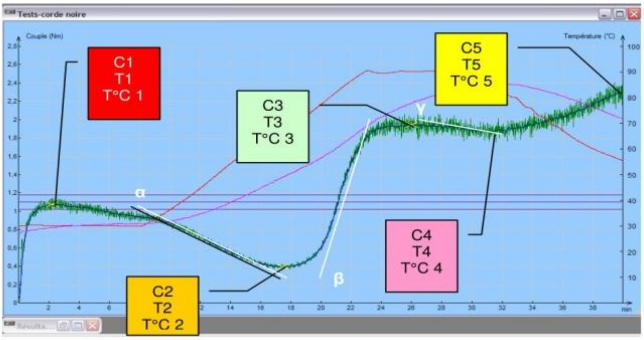


Fig. 19. The Mixolab Device (Chopin) (Anonymous, 2009) **Fig. 20**. The Mixolab Dismantled **Fig. 21.** A detailed image of the Mixolab



Point	Significance	Associated parameters	
C1	Used to calculate water absorption	T°C 1 and T1	Dough temperature and the time taken for different types of torque to appear
C2	Measures protein weakening as a function of mechanical work and temperature	T°C 2 and T2	
C3	Measures starch gelatinization	T°C 3 and T3	
C4	Measures the stability of the hot-formed gel	T°C 4 and T4	

Fig.22. Mixolab Profile Recorded Using (Chopin+ protocol) (Anonymous, 2009)

-The Glutopeak: With Glutopeak device, gluten quality can be distinguished in a short time and with a small amount of sample. In this device, the aggregation properties are measured by applying a high mixing force to the flour-water mixture. In order to determine the gluten quality, gluten is separated first; Then the gluten network is formed and the network formed by the continued rapid mixing is disintegrated. The time taken to reach the maximum point, the peak height and the decrease in the following peak are the basic information in gluten quality assessment and can be measured in a very short time (Anonymous, 2017b). The device automatically evaluates and gives the resistance at the maximum peak and 15 s. before and 15 s. after the maximum peak. Karaduman et al. (2015) reported that Glutopeak parameters can be used to determine gluten quality in a fast, easy and reproducible manner.

			Chemical composition of cereals (as a percentage of the dry matter				
	water	Starch (% of moist grain	azoted matter total	Lipides	Gross cellulose	Mineral matter	main forms of consumption
Soft wheat	13,8	65	12,5	2	2,7	2,7	flour for the baking and Pastry industry, Animal feed
Durum wheat	13		15,7	2,3	2,9	2	semolina (couscous, pasta, boulgjour Animal feed
Spelt (Cereal Quite similar to wheat but protected- the grain remains covered by its ball when harvested)							Flour for the Baking and Pastry Animal feed
Barley	13,3	60	12,1	2	5,6	3,6	Beer, Animal feed
Buckwheat	13		13,1	2,8	11,6	2,4	Flour for pancakes, pasta, Animal feed
Rye	13,5	63	12	1,6	2,6	2	Flour for the Baking and Pastry, Animal feed
Tritical e (Hybrid cereal created at the start of the seventies. Cross between soft wheat and rye)	12,9	64	13	1,7	3,3	2,2	Flour for bread, pasta ,tortillas and cakes Animal feed

Fig. 23. Cereals Tested by Mixolab (Anonymous, 2009)

QUALITY AND EVALUATION OF BARLEY

Quality criteria are directly related to the use of variety, certified seed, climate and cultivation technique (Kendal and Duzgun, 2014). The concept of quality in barley varies according to the area of use of the product. Most of the barley is consumed as animal feed. A good feed barley has flat bones, high digestibility, high lysine content, which is one of the essential amino acids affecting its nutritional value, high protein amount and quality (12-15%), low cellulose ratio (5-6%), high thousand grain weight (35 -50%), high hectoliter weight (60-70%), low husk ratio (less than 10%) and foreign matter content less than 1% are desired (Anonymous, 2015).

The dietary fiber content of barley is higher than that of the common cereals. The β-glucan content of barley is also a projecting value. Another important area of use of barley is the malt-beer industry, and the quality parameters and values sought in barley in this area differ from feed barley, They are showed in Table 8. by Sipos (2013).

Table 12. Quality Requirements for Barley for Forage Use (Sipos, 2013; MSZ 6372-78)

Parameter	Requirement
Specific weight, min	63 kg/hl
Impurity, max	2,0%
in which harmful impurity, max	0,5%
Light impurity, max	0,5%
Allowed rate of broken grains, max	5,0%
Sum of rye and oat, max	10%
Moisture content, max	14,5%

Table 13. Quality Requirements for Malting Barley (Sipos,2013; MSZ-08 1326-79)

Parameter	Base	Limit
Specific weight, kg/hl	68,0	min 65,0
Purity, %	98,0	min 96,0
Impurity, %	2,0	max 4,0
in which valuable impurity, %	1,5	max 3,0
valueless impurity, %	0,5	max 1,0
harmful impurity	0,2	max 0,5
Gradedness		
Grains with full value (2.5 mm sieve), %	75,0	min 70,0
screenings in 2.2 mm sieve, %	4,0	max 5,0
germinating ability, %	95,0	min 90,0
Moisture content, %		14,5
Protein content in dry matter content	11,5	max 12,5

QUALITY AND EVALUATION OF RYE

One of the grains suitable for bread making is rye after wheat. The parameters in its chemical structure (starch, protein, carbohydrate, oil and ash content) are similar to those of wheat. The limit value of hectolitre weight for food use is 71 kg/hl and for feed use 67 kg/hl. The maximum values of harmful seeds and ergot are 2%, 0.5% and 0.2%, respectively. The maximum values of impurities, broken grains and germinated grains for food use are 0.5%, 3% and 2%, respectively, for feed use 0.5%, 10% and 5% respectively. Maximum requried moisture content is 14.5% (Sipos, 2013).

Protein ratio of rye grain is slightly lower than wheat. The protein, which is 11% (6-12) on average, consists of 42% gulutenin, 42% gliadin, 8% globulin and 8% albümin (Anonymous, 2015). Among the cool climate cereals, the most nutritional fiber is found in rye at the rate of 15-17% in whole grain, 10-13% in bread wheat and 11-13% in the hulled oat experiment. It has been reported that wheat flour without bran has only 3% dietary fiber. In addition, the outer layer of rye grain endosperm is rich in proteins, minerals and vitamins, especially B-vitamins (Anonymous, 2015). There is an average of 11% protein, 2% digestible oil, 2.5% crude fiber and 60% starch in rye populations in our country, although there is variation among the populations. Thousand grain weight is 20-30 g. Hectoliter weight is 70-75 kg.

QUALITY AND EVALUATION OF OAT

Although oats are evaluated in different areas of use, there are no quality standards established for these areas yet. The most general characteristics are hectolitre weight, hull ratio, hulled kernel weight and hulled kernel composition to describe grain oat quality. Some important groin grain traits in relation to quality are protein, fat and beta glucan content (Anonymous, 2015).

Oats show the highest difference in chemical composition from other grains. Protein content is about 10 to 13%, slightly less than that of wheat, but essential amino acid concentrations are higher (about 50% of amino acids are essential), and Naked Oats varieties have 20 to 30% higher protein content. It has significantly lower starch content than other grains, about 55% overall. Oats are rich in lipids, this widely grown grain has the highest lipid content with a value of 5% to 7%, and this lipid content is rich in essential fatty acids. Oats, at the same time, 8% and 12%, ranging from a high fiber content, and this, glucan-containing cereals is a value of conspicuous; a water-soluble polysaccharide, acts as dietary fiber consumption during many advantageous health effects.

Quality requirements for oats do not focus on chemical composition. The purity must be less than 0.5% and no more than 98%, which is left for the same ratio for the amount of harmful seeds and mild impurities. Wheat, barley and rye are allowed to reach a maximum concentration of 10%. The moisture content should be no more than 14.5% and the minimum hectoliter weight should be higher than 22 kg/hl according to the requirements of the Hungarian codex standard complements the requirements for protein content (10.65%) and starch value (54.34 kg /100 kg). It does not make specific claims on food use, but some countries require higher hectoliter weight (e.g. in Australia the limit for first quality is 51 kg/hl) but similar values are required for impurity, screening and moisture content.

NEW TECHNOLOGIES FOR GRAIN QUALITY ANALYSIS

Quality is a quantitative character with a complex inheritance, controlled by multiple genes, under the influence of genotype-environment-breeding technique interaction. Recent developments in biotechnology and techniques such as molecular markers are beneficial in determining both breeding and quality parameters of cereals in more detail.

Significant efforts are needed both now and in the future in quality improvement and other breeding. New techniques are needed that will provide advantages in terms of time and chemical consumption and also economical. NIR (near infrared) technique, (DIA) digital image analysis, DNA-based procedures, It is important to develop techniques such as ICP and AAS. Also, rheological instruments and molecular marker techniques may be techniques that will become more important in the future. (Lásztıty and Salgó, 2002)

NIR whole kernel transmittance is now used extensively in the measurement of protein, moisture, ash, wet gluten content, hardness and other parameters of grains (Delwiche, 2010).

The working principle of the NIR spectrometer, which has recently been widely used by grain organizations, analyzes the invisible near-infrared (IR) light region. The sample given to the device is exposed to IR beam. Molecular absorbed or reflected energy at certain wavelengths creates a certain boundary reaction, which can be symmetrical or asymmetric stress or shear and alters the reflected light. Specific wavelengths refer to chemical components by the active part of the molecule (ex.–CH groups, or -OH), because changes in light intensities measured at different wavelengths characterize the amount of molecules. IR devices are divided into reflectance(NIR) or transmittance (NIT).Analyzes of organic and inorganic materials in solid, liquid and viscose phases can be performed with the Near Infrared Spectroscopy device (Kendal and Duzgun, 2014). Spectra detected are evaluated and transformed by multivariate statistical methods, resulting in a good prediction for protein, moisture, fat and other quality parameters. However, new and hard studies are needed to detect micro components, for example the presence of toxic substances on cereal grains (Sipos, 2013).

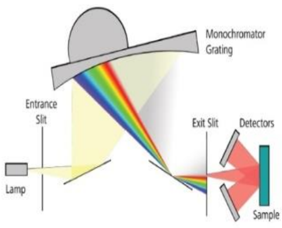


Fig.24. Scheme of NIRS (Anonymous, 2021f)

Fig.25. The NIR Device (Anonymous, 2021g)

-**Mineral Elements:** The concentrations of the mineral elements found in cereals are generally trace and low, but their amounts are very important for nutrition. They have functions such as essential, non-essential, toxic and non-toxic. Some elements can be both toxic and essential (e.g. selenium). Micro and macronutrient concept those with concentrations higher than 0.1% (e.g. Ca, Mg, Na, K, P, Cl and S) are considered as macronutrients. Micro nutrients are substances with trace amounts (e.g. Cr, Co, Zn, Cu and Mn).The spectroscopy can be performed emission or transmission method (e.g. ICP-AES, AAS) for determination of elements in cereals.

-Total Antioxidant: Total antioxidant activity can be detected by indirect and direct methods. Measurement of free radicals cleaning activity of the sample is evaluated as an indirect method. The evaluation of the stability of lipid substrates containing antioxidants is known as the direct method. According to a modified method by Yu et al.(2002), the total phenolic substance can be determined. According to Huang et al. (2005), the color formed by the destruction of the DPPH (2,2-diphenyl-1-Picrylhydrazyl) radical, a pink-colored stable compound, is measured spectrophotometrically.

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CHAPTER 7

YELLOW DWARF VIRUS DISEASES THAT CAUSE ECONOMIC LOSSES IN CEREALS AND MANAGEMENT METHODS

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INTRODUCTION

According to İlbağı (2016), ‘Cereals; It ranks first among nutrients due to its high carbohydrate-based energy providing feature, its easy and cheap production compared to many plants in agricultural production, its being a concentrated energy source, its satisfying feature, its partial protein content and its unyielding taste and aroma (Elgun and Ertugay, 1990)’. Among the cereals in the world, the cultivation area, production and consumption amount of wheat is high. In addition, the first plant grown in cereals is wheat (IGC, 2018; Karaman, 2020).

Wheat, which is the most produced product after maize and rice among the grains in the world, is the homeland with 28 wild wheat varieties found in our country. There are hundreds of local varieties of wheat in Turkey. As of 2016, there are a total of 259 types of registered wheat, including 198 types of bread and 61 types of durum wheat. Today, wheat is grown in a wide range of geographies and various climates, from tropical countries to the south of America, from mild climates to the north of Europe (Ozberk et al. 2016).

As reported by İlbağı (2016), ‘In todays conditions, increasing air temperatures with the effect of changing climatic conditions cause an increase in diseases and pests, resulting in economic losses in the product. Yellow dwarf virus diseases, which are quite widespread especially in high grain production potential provinces of Turkey. It cause epidemics from time to time, and significant losses in grain yield and quality of grain types such as barley and oats, especially winter bread and durum wheat'. This virus disease which causes yield losses between 11-33%, colud be causing yield losses at rates exceeding 80% in some fields, although it changes over the years (Pike, 1990).

İlbağı (2016) reported, 'This virus was previously very rare in Turkey however, it started to observe in some other provinces in 2000. It was especially determined in the winter bread wheat grown in the millet fields cultivated in Tekirdag province and infection rate was found as 61.63% (İlbağı 2003, İlbağı et al., 2005). This disease has resulted in epidemics in grain production areas of the Thrace region, especially in Edirne province in April 2016. It has been observed that the disease causes 40-70% loss of the yield and quality in winter bread wheat and barley fields, in areas sown in October 2015 and where susceptible varieties are cultivated. In recent years due to global warming and increasing air temperatures the virus diseases transmitted by aphids significantly increased and, consequently, the loss of product and quality were observed. It is a fact that these diseases, which are carried by aphid species, which increase in the coming days, will produce grain that will produce grain. The methods of combating these diseases, which show more severe effects in all grain types, especially in wheat, barley and oat fields, have been determined by different project studies (İlbağı and Çıtır 2012; İlbağı, 2013)'.

YELLOW DWARF VIRUS DISEASES CAUSING YIELD AND QUALITY LOSSES IN CEREALS

International Committee on Taxonomy of Viruses listed ten virus species that cause the disease syndrome known as barley yellow dwarf. All of these species belong to the family *Luteoviridae* and based on the host range, genome organization, sequence similarities and gene expression strategies, luteovirids have been grouped into three recognized genera namely; Luteovirus, Polerovirus and Enamovirus (Ali et al., 2018).

Based on predicted amino acid sequence similarities and vector-aphid type, the genus Luteovirus has been classified into eight recognized species, as BYDVKerII, BYDV-KerIII, BYDV-MAV, BYDV-PAS, BYDV-PAV, RSDaV, SbDV and BLRV (Svanella-Dumas et al. 2013; Domier 2011; Adams et al. 2014) BYDV- PAV is a widespread srotype and a type spescies of the genus Luteovirus (Mayo and D'Arcy 1999). The genus Polerovirus includes at least 31 virus species which are transmitted to diverse plants by aphid species in a circulative and persistent manner (Fereres and Raccah 2015). Barley yellow dwarf (BYD) is caused by any one or a complex of closely related viruses comprising two main genera barley yellow dwarf Luteovirus (BYDV) and cereal yellow dwarf Poleovirus (CYDV) (Liu et al., 2007).

BYD causes a significant reduction in cereal grain production. In wheat, yield losses are estimated to be form 13-25 kg/ha (McKirdy et al. 2002) to 27-45 kg/ha (Banks et al. 1995). Up to 80 % yield loss of cereal crops due to BYDV and/or CYDV infection has been reported, which is caused by reduced numbers of tillers per plant, seeds per tiller, and seed weight (McKirdy et al., 2002; Perry et al., 2000).

The transmission efficiency of each virus species depends, in part, on the vector species (Rochow, 1969; Johnson and Rochow 1972). BYDV-PAV is transmitted most efficiently by *Rhopalosiphum padi (Linnaeaus)* and *Sitobion avenae*, BYDV-MAV specifically by *S. avenae*, CYDV-RPV specifically by R. padi, MYDV-RMV by *Rhopalosiphum maidis*, and BYDV-SGV most efficiently, but not specifically, by *Schizaphis graminum* (Rochow, 1969; Johnson and Rochow 1972). The tranmission of BYDV by aphids is persistent, circulative and non-progrative manner. The virus can survive in the vector for 2-3 weeks. The virus is not transmitted to the next generation. There is a latent period during which virus retrieval takes less than 1 day. However, since the virus is received and transmitted in less than 1-2 minutes, transmission is easy (Deligoz et al., 2011; Çapkan, 2015) (Figure 1).

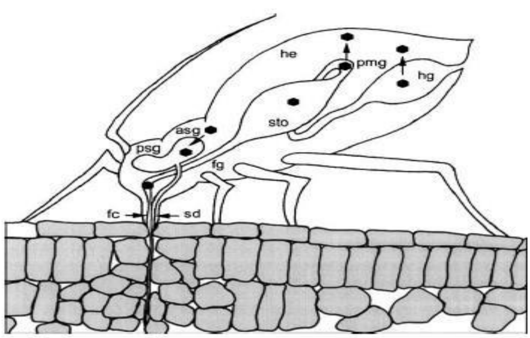

Figure 1. Virus transport during the penetration of aphids into plant tissue (Brault, 2007).

R.padi is an efficient vector for both BYDV and CYDV, and is therefore the most damaging aphid species (Gourmet et al. 1994).

As reported by İlbağı (2016), ‘Yellow dwarf virus diseases causes disease in common wheat, durum wheat, barley, oats, rye, triticale,maize, millet, rice and sorghum. At the same time, it causes infection in single and perennial weed species and meadow grasses, most of which are members of the *Poaceae* family. Yellowness and dwarfness are the most characteristic symptoms of the wheat. Barley gets a high bright yellow color, if maize turns to a yellow, purple or reddish coloration. The most typical symptom of oats is red, purple and yellowness (Figure 2). Likewise, the typical signs of yellowness and dwarfness are the most characteristic symptoms in triticale, millet and rye. Local symptoms of yellowness and dwarness in cereal fields are the most typical symptoms (Figure 3).

However, these symptoms can be confused with the symptoms caused by heat stress, nitrogen and phosphorus deficiency. (D’Arcy and Burnett, 1995).

a b

c

Figure 2. Yellowness and Dwarness Caused by Yellow Dwarf Virus Disease in Wheat (a), Oats (b), and Symptoms of Redness in Maize (c) (İlbağı, 2020).

a

b

Figure 3. Local yellowness and dwarfness symptoms caused by yellow dwarf virus diseases in wheat (a) and barley fields (b) (İlbağı, 2016).

MANAGEMENT METHODS OF BARLEY YELLOW DWARF VIRUS DISEASES (BYDVD)

As determined by İlbağı (2016), ‘Since these diseases caused epidemics in the past, as this year, the criteria for management yellow dwarf virus diseases were determined by both field trials and laboratory tests’. General management strategies fort his complex disease can be as follow:

- Accurate diagnosis is the first step in BYDVD management. It is diffucult diagnose it visually since symptoms can be similiar to those caused by other disease or environmental factors.
- Genetic resistance: The cultivars with documented resistance or tolerance for barley yellow disease vıruses (BYDVs) should be used. Some wheat, oat and barley varieties have good levels of resistance or tolerance.
- Timely seeding: Plant winter wheat as late as practical in fall to avoid potential aphid activity in early fall summer crops and grasses mature. For spring seeded small grains, planting as early as possible allows them to reach a more advanced stage of development before aphids arive and multiply,reducing the potential for yield loss.
- Cultural management: control grassy weeds volunteer cereals. These plants can harbor BYDVs, which can then be transferred to the main crop by aphids.

According to İlbağı (2016), ‘As a result of the 3-year study in Turkey, there commendations to be implemented are determined as follows:

a) proper variety selection is important: Varieties with high yield and quality, resistant to disease or tolerant, adapted to every region should be planted and trying different varieties every year should be avoided.
b) late sowing date significant: Winter bread wheat and other winter cereals should be sown in November (Figure 4).

Figure 4. On the left, where late sowing (November) takes place in the same production area when the disease has not observed in the field on the right, where the sowing takes place in October Yellow dwarf virus disease has observed significantly affects the wheat field (İlbağı, 2016).

c) great emphasis should be given integrated fight against virus vectors

d) sowing rotation must be applied

e) stubble sowing should not be done

f) should be management with weeds

g) avoiding too much seeding and frequent planting

h) balanced and appropriate fertilization to soil analysis reports’

CONCLUSION

Barley yellow dwarf can be a devastating disease of cereals. The biology of the aphid vector, plant host and BYD viruses are quite complex and have made prediction of disease difficult. The control of the disease has evolved over the years since it first became a problem. Since the viruses causing BYD are vectored by aphids, physical barriers have been implemented to prevent virus spread. Plastic reflecive mulch can be placed around the crops. UV wavelengths will be reflected, thus repelling the aphids. Floating row covers with a fine mesh can also physically bock the aphids from reaching the plant. Mineral oils and aphicides can also be succesfully applied. Carefully planned planting can reduce virus transmission by aphids. This strategy can then be combined with pesticide use at the right time. As a result of the studies performed up to now in Turkey. İt has been observed that barley dwarf viruses are an epidemic level especially in wheat production. Besides it is uncertain if it would be caused high loss in the future as it does in different parts of the world. Therefore, preventative measures should be applied carefully to limit BYDVs exposure and resistant or tolerant varieties should be developed to fight infection directly.

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CHAPTER 8

WEED TROUBLE IN WINTER WHEAT

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INTRODUCTION

It is known that weeds compete with the crop for light, nutrients, water and place. They also cause indirect damage by hosting pathogens and insects. In order to prevent these economic losses, it is necessary to determine the problematic weeds in the wheat fields and to develop the appropriate control method. When the weed species that are problematic in wheat are examined, it is seen that wild mustard, cleavers, corn buttercup, wild oat, ryegrass, crabgrass, downy brome, and black grass stand out. For this purpose, preventive / cultural measures, physical / mechanical control, biological / biotechnical tactics or chemical control can be done. In terms of practicality, the most preferred method is chemical control by active ingredients. Although most herbicides, with the exception of total herbicides, are known to be crop selective and control certain weeds, sometimes the risk of phytotoxicity is high with some herbicides. Herbicide applications are available before planting, pre-emergent and post-emergent in chemical control. Wheat is very sensitive to early weed competition. Weeds generally compete effectively with wheat in the early period, when the wheat has few leaves and in the early period of tillering. This early period of wheat is defined as a critical period in terms of weed control. If an effective control is made during this period, the crop will cover the soil and thus the weeds will be suppressed. Thus, in recent years, it is seen that herbicides such as pyroxasulfone, which can be used in the pre-emergence period of wheat and weeds, have also started to be used. Usually, it is seen that the most preferred method is tillering of wheat after emergence and the period when the weed has 2-

6 leaves. For example, weed spraying for the Southeastern Anatolia Region for winter wheat can be done in the period from the beginning to the end of March. It is important that the wheat is not in the stall period. Otherwise, problems may occur due to phytotoxicity and stem breakage. Weeds are also an important problem before and during harvest. Green weeds make it difficult for the combine harvester to work and harvest. In addition, weed plants or seeds mix with the harvest crop and contaminate the crop. Pre-harvest and harvesting herbicides can be used to prevent this situation. However, in such applications, attention should be paid to the selection of appropriate herbicide and the time of application. Otherwise, it is inevitable to encounter efficiency, quality and residue problems. Generally, we can say that grass weeds and broad-leaved weeds can be sprayed at the same time. While using clodinafop, fenoxaprop, pinoxaden and mesosulfuron against grass weeds, tribenuron, thifensulfuron, iodosulfuron, triasulfuron, tritosulfuron, pyroxsulam, foramsulfuron, sulfosulfuron, 2.4-D amine, 2,4-D ethylhexyl ester, dicamba, MCPA, clopyralid, and bromoxynil are used. In order to achieve success in chemical control, it is essential to apply the right herbicide at the right dose, at the right time, by the right application tools and by the right people. For this reason, field visits should be made at regular intervals before and after wheat planting, weed species should be identified, economic damage thresholds and critical periods of weeds should be followed. For this purpose, farmers may need to get support from Agriculture and Forestry Provincial / District Directorates, Cooperatives, Unions or Freelance Consultancy Firms. For the control of harmful alien species causing

problems related to herbicide to be applied in Turkey, the Ministry of Agriculture and Forestry of plant protection products is necessary to use the database of registered herbicides. Label information of herbicides to be used must be read. Particular attention should be paid to the problematic biological activity, product selectivity, resistance risk and miscibility of the herbicide. For biological efficacy, application principles must be followed. Herbicides with high selectivity should be preferred instead of herbicides with phytotoxicity risk. Herbicides with different action mechanisms should be rotated in order to delay the risk of resistance. As a result, weeds cause significant economic losses in wheat and herbicides are the most widely used methods to prevent these losses, but be careful with the use of herbicides.

1. PROBLEMATIC WEEDS IN WHEAT

Weeds are one of the most important threats to wheat production (Pala and Mennan, 2017). Weeds constitute major losses and contamines to crops which necessitates (Pala et al, 2018). Among the weeds that restrict weed production, annual, winter and grass weeds such as wild oat, ryegrass, canary grass, black grass and downy brome are seen to be at the forefront (Pala et al., 2020). These weeds, which belong to the Poaceae family, cause millions of dollars in economic losses every year (Peterson, 2007). The absence of crop rotation and the same maintenance procedures every year, in other words, monocultry agriculture, increases the frequency, density and coverage area of such weeds (Melander et al., 2013). The excessive and unconscious use of herbicides, which have the same effect mechanism against these weeds, whose phenological development is similar to cereals, for many years has caused difficulties in the control of these weeds (Nakka et al., 2019). These winter weeds, which are in the family of wheat, make their vegetative and generative development according to wheat, for example, they attach and shed seeds before the harvest of wheat to be a problem in the coming years (Suttie, 2002). It is inevitable to develop a herbicide-tolerant product to control these grass weeds for winter, although there are different herbicides licensed (Peterson, 2007). Polyculture agriculture should be used instead of monoculture in wheat production areas and integrated weed management should be implemented (Poggio, 2005).

In addition to grass weeds, some broad-leaved weeds are known to be an important problem in wheat fields (Young et al., 1996). Mustards, corn buttercup, and catchweed bedstraw are important winter annual broadleaf weeds (Pala and Mennan 2017). Mustard is the most common winter annual weed in winter wheat and has rapidly developed herbicide resistance (Nakka et al., 2019). The resistance case of wild mustard, which was first detected in 1983 against the PS II herbicide atrazine, was seen in the action mechanisms of Auxin (such as 2.4-D, dicamba, MCPA) and ALS (tribenuron, thifensulfuron, sulfosulfuron, iodosulfuron) in the following years. This situation indicates that the problems will increase with the control of this weed today and in the coming years (Heap, 2021).

It is known that when crop rotation (for example, wheat-lentil-barley-chickpea in dry agricultural areas and wheat-cotton-corn-soybean in irrigated agricultural areas) is applied at least 3-year rotations, broad-leaf weeds are reduced (Pala 2019; Guareschi, 2021). In crop rotation, weeds are suppressed both due to the products that are highly competitive with weeds and because different weed control tactics are applied, especially the use of different herbicides (Pala, 2019). It was determined that the diversity of broad-leaved weeds decreased in agricultural areas where crop rotation was applied (Koocheki et al., 2009).

Table 1. Common weeds in winter wheat (UCANR, 2021)

Scientific Name	Common Name
Aegilops cylindrica	goatgrass, jointed
Amaranthus retroflexus	pigweed, redroot
Amsinckia menziesii	fiddleneck, coast
Anagallis arvensis	pimpernel, scarlet
Anthemis cotula	chamomile, mayweed
Avena fatua	oat, wild
Bassia hyssopifolia	bassia, fivehook
Brassica spp.	mustards
Bromus diandrus	brome, ripgut
Calandrinia ciliata	redmaids (desert rockpurslane)
Capsella bursa-pastoris	shepherd's-purse
Centaurea solstitialis	starthistle, yellow
Chamaesyce humistrata	spurge, prostrate
Chamomilla suaveolens	pineapple-weed
Chenopodium album	lambsquarters, common
Chenopodium murale	goosefoot, nettleleaf
Claytonia perfoliata	miner's lettuce
Convolvulus arvensis	bindweed, field
Cyperus esculentus	nutsedge, yellow
Echinochloa crus-galli	barnyardgrass
Erodium spp.	filarees

Galium aparine	cleavers
Hemizonia congesta	tarweed, hayfield
Hemizonia corymbosa	tarweed, coast
Hordeum leporinum	barley, hare
Kochia scoparia	kochia
Lactuca serriola	lettuce, prickly
Lamium amplexicaule	henbit
Lolium multiflorum	ryegrass, Italian
Malva parviflora	mallow, little (cheeseweed)
Medicago polymorpha	burclover
Mentzelia spp.	stickleafs
Phalaris minor	canarygrass, littleseed
Phalaris paradoxa	canarygrass, hood
Picris echioides	oxtongue, bristly
Poa annua	bluegrass, annual
Polygonum aviculare	knotweed, prostrate
Polygonum lapathifolium	smartweed, pale
Polygonum persicaria	ladysthumb
Polypogon monspeliensis	polypogon, rabbitfoot
Ranunculus arvensis	corn buttercup
Raphanus raphanistrum	radish, wild
Salsola tragus	thistle, Russian
Senecio vulgaris	groundsel, common
Setaria spp.	foxtails (yellow and green)
Silybum marianum	milkthistle
Sinapis arvensis	wild mustard
Sisymbrium irio	rocket, London
Sonchus asper	sowthistle, spiny
Sonchus oleraceus	sowthistle, annual
Sorghum halepense	johnsongrass
Spergula arvensis	spurry, corn
Stellaria media	chickweed, common
Urtica urens	nettle, burning

While weeds for winter such as wild mustard and shepherd's purse are a problem in winter wheat production areas, summer weeds such as bindweed and pigweed are a problem in spring wheat fields (Wicks, 2000, Pala and Mennan 2017). Water-loving weeds such as rough bluegrass come to the fore as a problem in rainy years (OMAFRA, 2021). Volunteer barley in barley-wheat crop rotation production areas, similarly volunteer lentil in lentil-wheat rotations (Al-Ajlouni et al, 2010; Gan, 2017).

Monoculture farming areas feel more weed pressure than polyculture farming areas (Poggio, 2005). Wild oat, one of the most important weeds, germinates in autumn with the wheat plant and starts competition, and competition with the crop increases especially in the spring during the active development period (Beckie, 2012; Pala and Mennan 2017). This reduces weed yield and quality, as well as making it difficult to harvest (Anderson and Garlinge 2000). In areas where weeds are dense, a straw harvester should be used and the straw should be collected (Khan et al, 2007). It is worth repeating that crop rotation is an important factor in the control of grass-shaped weeds (Koocheki, 2009).

Among the products to be rotated, fiber plants such as cotton with high cash value, a strategic product such as corn with high weed competition and leaving a clean field after it, or legumes such as lentil that binds nitrogen to the soil can be preferred. In this case, besides economic concerns, sustainable agriculture practices should also be taken into account (Angus et al., 2015). We can say that grass winter weeds are a more important problem in dry farming areas, especially in monocultural farming areas, and this problem is growing every year (Lee and Thierfelder 2017). When broad-leaved crops are alternated in irrigated farming areas, the control of grass weeds is more comfortable, especially with herbicides, so the management of such weeds is more comfortable (Jabran et al., 2017; Mennan et al., 2020).

Consequently, although it varies according to the region, grass and broad-leaved, single or perennial weeds can be seen in wheat. The rate of loss caused by these varies according to the geography, environmental conditions, the wheat variety produced, the type of weed and its density in the field, and the development periods of both wheat and weed. Wild oat species, wild mustard, canary grass species, yellow grass, cocarot, Italian grass, tufted meadow and foxtail are some of the weed species that are harmful to wheat.

Weeds do not only cause a decrease in productivity in the field as a result of competition. At the same time, by mixing with the main product, the value of the seed decreases and flour in the product to be made flour; It also causes a change in color, odor and structure, that is, a decrease in quality. On the other hand, it can cause many disease factors and pests to increase their level of damage by hosting them. Knowing the growth period of wheat is important in deciding the management.

Traditional tillage and herbicide use is common in weed control, but it is predicted that clearfield, drone and allelopathic materials will be developed and expanded in the near future (Safi and Al-Faid, 2018).

a. Identıfy Weeds in Wheat

There are four different groups such as broadleaf, grass, sedge and aquatic used in the diagnosis of weeds (UCANR, 2021).

Broadleaf: The seed is dicotyledonous. Roots are piles. Conduction bundles are smooth, they have cambiums (May form age rings). Leaves are reticulate. Flower petals are 4-5 or its multiples.

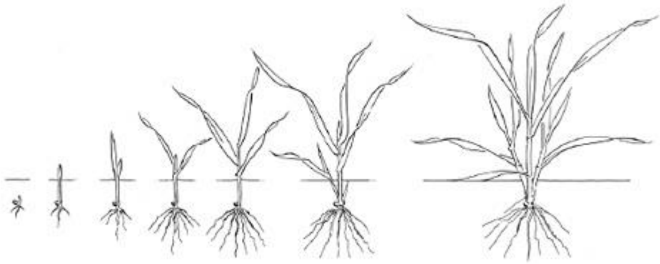
Grass: The seed is monocotyledonous. Roots are fringe. Conduction bundles are scattered, they do not have cambiums (cannot form age rings). Leaves have parallel veins. Flower petals are 3 or multiple.

Sedge: Leaves are narrow, arranged in sets of three; stems are triangular in cross section. Sedges are perennial plants that are commonly found in shallow water or moist soils and can reach 4 feet in height.

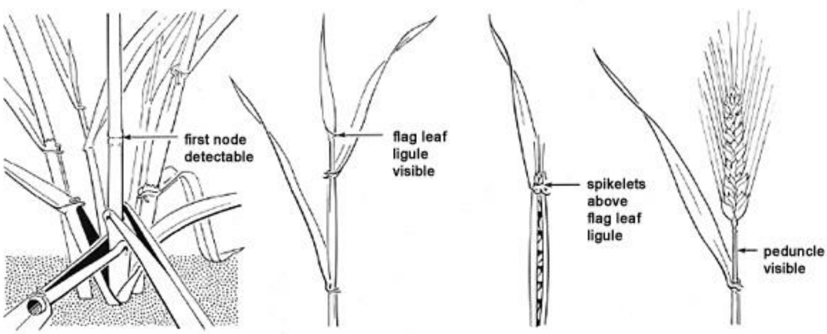
Aquatic: Plants that grow in water for at least part of their life cycle. They may occur in the whole body of water as submerged, or may appear to cover the whole surface of the water as floating weeds.

b. Developmental Growth Stages

Knowing the growth period of wheat is important in deciding the control tactics (UCANR, 2021).



Growth stages	Emergence	One-leaf	Two-leaf	Three-leaf	Tillering begins	Well-tillered
Feekes	1	1.1	1.2	1.3	2	4



Growth stages	Jointing begins	Last leaf just visible	Early boot	Heading begins	Heading complete
Feekes	6	8	9	10.1	10.5

Figure 1. Phenology of wheat

Herbicides can be applied from the 2-3 leaf period of the wheat to the end of the tillering period. Since the application of herbicides after the wheat is removed from the stalk may cause phytotoxicity in the wheat. and ineffectiveness in the control of weeds.

2. CHEMICAL WEED CONTROL FOR WHEAT

In order to eliminate the threat from weeds, it is necessary to correctly identify and control weeds (van der Meulen and Chauhan, 2017). For weed control, appropriate cultural, mechanical and chemical control methods should be used (Lee and Thierfelder, 2017). Yield and quality are also low in dry farming areas, especially in monoculture areas. Since the economic return is low, farmers avoid weed control in order not to increase input. However, unfortunately, the weed problem in these areas is more annoying than in watery areas(Abouziena and Haggag, 2016).

It is very important to decide on the herbicides to be used against weeds in wheat, because herbicides directly affect the weeds and this effect is reflected in the yield (Safi, 2016). Since weed control in wheat is generally carried out after emergence, whether in dry farming or irrigated farming areas, accurate diagnosis of weeds is important in terms of developing a correct control strategy (Sosnoskie et al., 2006). For weed surveillance, field visits should be made from the period when the weeds have two or three leaves. The densities of the weeds should be determined by throwing the frames. Situation analysis can be done after determining the weed species and densities. For example, having 5 wild oats or 1 wild mustard per square meter means that there is a problem (Booth et al., 2003).

Since it is known that the weed problem begins with wheat cultivation, a total of three fertilizers with base fertilizer and two top fertilizers for a strong crop can increase the competition of the crop with weeds

(Habimana et al, 2014; Lee and Thierfelder, 2017).

Wheat, which is generally sown in autumn in November, can be sprayed with herbicides after germination from the two-three-leaf period to the tillering period. If the weed density is very high, spraying can be done in the early period, but it is known that spraying is usually done in March. In places with high altitude, this may delay to April. (Gaba et al., 2016). There are several different herbicides available for use in grass and broad-leaf weed control after emergence (Canevari, 2006; PPP, 2021).

Table 2 Herbicide Treatments in Winter Wheat (PPP, 2021)

2,4-D amine	The best results are obtained when 2.4-D amine is used in the period when weeds are growing rapidly. Do not apply if the temperature is lower than 10-12 ° C. It is not recommended to mix with other plant protection products. If a mixture is needed, a premix test should be done.
2,4-D ethylhexyl ester	Cereals (Wheat, barley): It is used from the period in which weeds complete their emergence until the end of the tillering period of the grain. The desired effect cannot be obtained and is not recommended if used after the period when the grains are up to the stem. Do not apply after frost or if frost is expected at night.

Dicamba	Broadleaf weed control after emergence. Since dicamba is taken up by the leaves and stems, it is applied in the 2-6 leaf stage of weeds after emergence in wheat and corn. 20-30 liters of water should be used per decare. In order not to wash off the product from the plant, it should not rain for 4-5 hours after application. Air temperature above 10 °C during the application period increases the effectiveness of the drug.
MCPA	Since it is a herbicide used after emergence, it can be applied after emergence of weeds. It should be thrown with 20-40 liters of water per decare with back sprayer or standard arm sprayers. In order to get the best result from MCPA products, it should be applied in the period when the weeds have 2-3 leaves or when the rosette leaves. A good coating should be applied in the application. Care should be taken to keep the air temperature between 10 and 28 °C during the period when MCPA is applied. It is not suitable to apply when the plant surface is wet. If it is expected that it will rain after 4 hours, spraying should not be

	done. Wheat should have at least 3 leaves during the period when the pesticide is applied. The period from the 3-leaf period to tillering is the most appropriate period for spraying.
Clopyralid	Wheat: It is used in the tillering period of the wheat, in the 2-4 leaf stage of the scent grass.
Bromoxynil	While the grains are between the 2-4 leaf period and the full tillering period, the best results are obtained by coating spraying to be applied before the competition for the water and nutrients in the soil (2-4 true leaves period). Cultivated Plant: It is used between 2-4 leaves and tillering period of the plants. Harmful Organism: Weeds are applied in the period of 2-4 true leaves or 3-5 cm diameter.
Tribenuron methyl	It can be used safely from the 2-leaf stage of the cereal to the scabbard (in Virgo scabbard). Since it provides great flexibility in terms of application time, weeds, which are a problem in the application time, are taken when they are in at least two-leaf stage but before reaching a height or diameter of 15 cm and when

	the weeds are in at least two-leaf stage and only before reaching a height or diameter of 15 cm and the top of the weeds are not covered by the grains. . In the fields where there is a lot of malt grass, spraying should be done in the rosette period when the Centaurea sp. has 7-8 leaves and reaches 8-9 cm in diameter.
Thifensulfuron methyl	It can be used safely in the period from the 1-2 leaf stage of the cereal to the scabbard period (spike in the sheath). The best result is obtained when the weeds are in the early development period, that is, when the weeds are in the 4-8 leaf stage. The growth of weeds stops shortly after application. However, death symptoms are seen 1-3 weeks after the application, depending on the growing conditions and the sensitivity of weeds. While hot and humid conditions after the application accelerate the effect of Thifensulfuron methyl, cold and dry conditions delay it.
Pyroxsulam	Both active ingredients of pyroxsulam systemic.

	It is used after emergence against grass and broad-leaved weeds in wheat. The drug is taken by the leaves and partially by the roots and transported to the growth points. Immediately after the drug is applied, weeds stop growing; Yellowing and dead tissue are observed on leaves and growth points 1-2 weeks after application; as a result, weeds lead to death within 3-4 weeks.
Florasulam	It is used from the period in which the weeds complete their emergence until the end of the tillering period of the cereals. The desired effect will not be obtained and it is not recommended if it is used after the period when the grains are removed from the stem. Do not apply after frost or if frost is expected at night.
Iodosulfuron	Hektaş Tesla® is a systemic drug, it is taken into the body through the leaves and partly roots of weeds and is transported to all parts of the weeds. Roots stop taking water and nutrients from the soil. Thus, the competition with the wheat plant ends in a very short time. Weeds

	are initially discolored and deformed and eventually dry up and die. Deaths occur within 2-4 weeks, depending on the species and growing conditions. Spraying should be delayed in stress conditions caused by cold weather and excessive rainfall. Using the same herbicide or herbicides with the same effect for many years in the same place may cause the resistant individuals found naturally in the environment to multiply and dominate the environment. As a result, these herbicides can cause weeds to become dominant with recommended doses. As a result, the recommended doses of these herbicides and the alternating use of herbicides against weeds, cultural measures and alternation delay or prevent the development of weed resistance.
Clodinafop	Clodinafop is taken from the leaves of grass weeds. Active growth in grass weeds sensitive to pesticides stops within 48 hours. Depending on the herb species and environmental conditions, the effects of the drug are seen within 1 to 3 weeks. Weed nodes and rot at growth points are visible, death occurs in

	young leaves following yellowing. It is not affected by the precipitation 2-3 hours after the application. The excipient in the formulation of the drug (safener); It increases the selectivity of the drug on wheat by promoting metabolism. When used in the recommended period and dosage, it is well tolerated by wheat.
Mesosulfuron	Mesosulfuron is a systemic drug that is taken into the body through the leaves and partly roots of weeds and is transported to all parts of the weeds. Roots stop taking water and nutrients from the soil. Thus, the competition with the wheat plant ends in a very short time. Weeds are initially discolored and deformed and eventually dry up and die. Deaths occur within 2-4 weeks, depending on the species and growing conditions.
Fenoxaprop	A good effect is obtained with a good coating spraying. It can be used with a sprayer suitable for field spraying. The amount of water used is 20-40 liters per decare. In spraying, if possible, a fan nozzle should be used and the pressure should be 3 atm. should be. It is not recommended to mix

	with other plant protection products. If a mixture is needed, the premix test should be done in a separate container.
Pinoxaden	Pinoxaden is a systemic herbicide used against grass leaf weeds in all wheat and barley varieties after emergence. Cereals have a wide range of uses, from the two true-leaf period to the flag leaf removal period. Pinoxaden is a DEN group grass plant protection product that is effective on enzymes not affected by these groups in addition to the enzyme systems affected by FOB and DIM group herbicides. It does not require the use of an additional spreader adhesive, as it is a spreader adhesive. In conditions where plants such as drought, frost, pest, disease and flood are stressful, the application should be avoided in the presence of these conditions, as low effect is expected.

In recent years, it is seen that the applications of 2.4-D EHE + florasulam and pyroxsulam or pinoxaden or mesosulfuron mixtures against weeds, which are a problem in wheat fields, have increased in the post-emergence tillering period.

Chemical control of weeds is one of the preferred methods. However, it should not be forgotten that chemical struggle alone is insufficient. The chemical struggle needs to be supported by tactics such as preventive / cultural measures (preventing the spread of weeds, sowing, irrigation, fertilization, use of certified seeds, crop rotation), physical / mechanical control (tillage, protected cultivation), biological / biotechnical (allelopathy, bioherbicides) tactics (Ateş et al., 2017; Kolay et al., 2020; Hammood and Safi, 2020).

CONCLUSION

Wheat is the most cultivated product in the world. Weeds compete with wheat, causing significant economic losses. Weeds also host other pests, complicate the harvest, and interfere with the harvested product, reducing the quality. Preventive / cultural measures, physical / mechanical control, biological / biotechnical tactics and chemical control methods can be applied to prevent this damage of weeds.

Weed control in wheat is carried out dependent on herbicides. This situation is due to the practicality of chemical control. Soil cultivation, alternation, herbicide rotation are important supporters for effective chemical control.

Winter weeds come to the fore in winter wheat. Species such as wild oats and wild mustard come to the fore. It can be said that grass weeds are more of a problem. While FOP and DIM group herbicides are prominent in the control of grass weeds, 2.4-D amine, 2.4-D EHE, MCPA, dicamba, clopyralid, bromoxynil are still widely used against broad-leaved weeds. In addition to these, tribenuron, thifensulfuron, triasulfuron, tritosulfuron, sulfosulfuron, mesosulfuron + iodosulfuron, pyroxsulam, fluorolam are also preferred. Weed treatment with herbicides in winter wheat is carried out during the tillering period of the wheat in the spring. Early and late spraying should be avoided during this period.

For effective weed control, certified seed, competitive variety, open field, tillage, soil disinfection, late and intensive planting, fallow, crop and herbicide rotation, sprinkler irrigation and adequate fertilization should be integrated for weed control. In the 21st century, alternative and modern techniques such as smart cultivators, sensitive sensors, robotic technology and drone diagnosis and control of weeds need to be researched, developed and disseminated.

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CHAPTER 9

INSECT PESTS IN THE CEREAL FIELDS OF THE SOUTHEASTERN ANATOLIA REGION

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INTRODUCTION

Wheat is the raw material of many foods that are important in human life. The adaptability of wheat is higher than other plant types, and it can be grown in different conditions (Karaman *et all*, 2020). Wheat production in the Southeastern Anatolia Region, located in the Karacadağ basin, which is known as the gene center of wheat, is under the influence of cultivar, environmental factors and agronomic practices (Başaran *et all*, 2020).

Wheat grown in the Southeastern Anatolia Region has an important place in our country in terms of its production and cultivated area. Diyarbakır, Şanlıurfa, Adıyaman, Mardin, Batman, Siirt and Şırnak provinces have an important place in terms of both production, yield and cultivated area.

Primary pests that are a problem in the cereal areas of these provinces; *Eurygaster integriceps* Put. (Sunn Pest), *Zabrus* spp. (Cereal ground beetle), *Pachytychius hordei* Brulle. (The cereal weevil), *Haplothrips tritici* Kurdj. (the wheat thrips) and *Syringopais temperatella* Led. (cereal leaf miner), while the secondary pests are *Anisoplia* spp. (wheat chafers), *Porphyrophora tritici* Bod. (ground pearles), *Cephus pygmaeus* L. (wheat stem sawfly), *Phorbia* sp (Wheat Land Fly), *Oulema melanopa* (L.) (oat leaf beetle)) and *Sitobion avenae* (F.) and *Rhopalosiphum padi* (L.) (the grain aphid). In addition, it is known that there are many beneficial species in cereal fields (Karaca et al., 2012).

In recent years, chemical pesticides have been used intensively by wheat farmers against Sunnpest, cereal ground beetle, cereal leaf miner and aphids. Chemical control practices are carried out by the farmers at an early stage. In other words, agricultural control practices start from the end of February and this practice continues until the beginning of April.

This chemical practice negatively affects the balance of beneficial and pest insects in nature in grain fields. Therefore, the priority in pest control these pests is to take into account the principles of Integrated Pest Control. First, cultural, then biological, biotechnical, and finally, if these applications cannot be obtained, chemical control should be applied for the control of pests.

In this chapter; Information about Sunn Pest, cereal ground beetles, wheat chafers, cereal leaf miner, wheat stem sawfly, the grain aphids in summer and winter cereals will be given.

1- SUNN PEST [*Eurygaster integriceps* Put., *E. maura* (L.) ve *E. austriaca* (Schr) (Hemiptera: Scutelleridae)]

Pest Description and Life

Although adult individuals of Sunn Pest species are generally earth colored, they can also be in black or red colors. In addition, Sunn Pest adults with mottled patterned colors, including all the above-mentioned colors, are also found in nature (Figure 1)

Figure 1. Overwintered Sunn Pest (left), Sunn Pest's nymph (right)

Sunn Pest adults have two life cycles, active and passive. The passive period lasts about 9 months (aestivation and hibernation period), the active period lasts about 3 months (feeding, mating). It spends the winter in mountains such as Karacadağ, Nemrut, and Hazarbaba in soft soil under plants such as *Astragalus* spp., *Acantholimon* spp., *Astragalus echinops* ,*Ouercus* spp. and *Pinus* spp. (Figure 2). The metabolic activities of sunnpest' adults accelerate with the melting of the snow and the warming of the weather in the spring, and the adults move from lethargic to active. In this period, the above-ground temperature in winter areas is 15 °C and above. With the formation of this temperature, overwintered Sunn Pest' adults migrate to the wheat and barley fields where they feed, mate and lay eggs. The nymph hatched from the egg continues to feed in the field until it becomes a new generation adult insect. After harvest, it is gradually pulled back to the mountains. It spends all the autumn and winter months, and the early part in the spring, in the mountain (winter quarter) in a stupor state. Sunn Pest gives one generation a year.

Figure 2. Karacadağ wintering site (left), *Acantholimon* spp. (right) and *Astragalus* spp. (below).

The way of doing damage to the plant and its economic importance

The amount and form of damage caused by Sunn Pest on the plant; It varies depending on the pest's biological stages (nymph and adult), density, wheat type and phenological period, climatic conditions. Wheat, barley, oats and the wild forms of these plants are the host plants of the sunnpest. Overwintered Sunn Pest' adults migrating to the grain fields in the spring suck the grain stalks, causing them to turn yellow and dry and therefore, these plants cannot come into ear. This form of damage is called "dry-heart leaves caused by overwintered adult" damage. Sunn Pest adults who have overwintered, which continue to feed on the upper parts of the plants, prevent the grain formation in the spike. This type of damage of the wintered Sunn Pest is called the "white spike" damage (Figure 3). The main damage in cereals is caused by the nymphs of the Sunn Pest. Sunn Pest nymphs (offspring) are pest during the ripening stage and dough stage periods of wheat. Wheat damaged in this way loses its bread and durum wheat properties, as well as the seed germination as a result of the damage.

Figure 3. White spike damage (left) and Sunn Pest nymph’s damage in wheat grain (right)

Enemies Of Sunn Pest

Food, ecological conditions and natural enemies play a very important role among the factors limiting the reproduction of the Sunn Pest in nature. Sunn Pest's natural enemies; egg parasitoids, egg predators, internal and external parasitoids of adults, adult or nymph predators (starling, partridge, quail etc.) and disease causing agents (entomopathogens: *Beauveria bassiana* (Balsamo), *Aspergillus candidus*). The most important natural enemies in this group are egg parasitoids (*Trissolcus* spp. (Hym.:Scelionidae) (Figure 4). Since this parasitoid is effective and suppresses the Sunn Pest's population, in some regions (such as the Thrace region), chemical control was not applied against this pest for some years (1989, 1990, 1991).

It is very important to create and protect an environment conducive to the reproduction of egg parasitoids. The most important way to apply this method is both afforestation around cereal fields and the roadside next to these fields and farmers' transition from monoculture agriculture to polyculture agriculture.

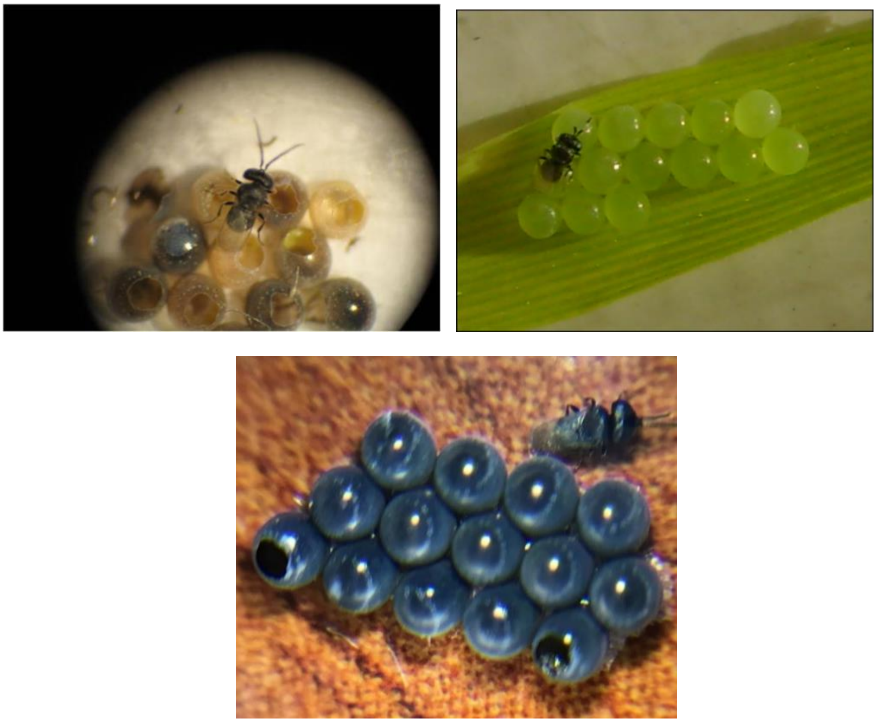

Figure 4. Sunn pest egg parasitoids (*Trissolcus* spp.)

Adult parasitoids (Diptera, Tachinidae) on Sunn pest (*Eurygaster integriceps* (Put.) (Heteroptera, Scutelleridae) are effective both in Sunn pest adults over wintering in winter areas and in cereal areas in the plain. Internal parasitoids (Dip .: Tachinidae) are *Phasia* *subcoleoptera* L., *Heliozeta helluo*, *Ectophasia crassipennis*, *Elomya lateralis*, external parasitoid is *Leptus* sp. (Acarina) (Figure 5).

In terms of ensuring the survival of Sunn pest-adult parasitoids in nature; It is very important to have plants such as lepidium campestre and corn mayweed (*Anthemis arvensis*) on the edge of the field and to protect these plants.

Figure 5. Sunn pest-adult parasitoid (left), parasitoid's larva (right) that emerged from the abdomen of the overwintered sunn pest's adult.

Applications out of technical instructions that may cause a decrease in the rate of interference in nature should be avoided. In order to protect and spread the effectiveness of natural enemies, green belt areas should be created by giving priority to trees with thick bark and nectar at the edges of the fields. It has been determined by previous studies that egg parasitoids overwinter in the trunk and under the bark of trees such as willow, almond, oak and mulberry. These plants, where the species that host egg parasitoids live, should be protected in nature, they should be widespread, and they should be included in the pasture and field edges and wooded areas. In order to ensure the survival of Sunn pest's adult parasitoids, it is of great importance to protect plants that carry nectar and grow spontaneously on fields and roadsides, such as country cress and field dog daisy (Duman et al., 2016) (Figure 6).

Cultural Control With Pests

Since early cultivation of early-grown grain varieties will be done early in the harvest, the Sunn pest will not be fed in these plants, so the damage to be caused will be prevented. Control against wild graminae on the edge of the field will prevent feeding of the overwintered Sunn pest adults who will come from the winter site to the plain. and thus the density of the pest will decrease.

With the emphasis on polyculture agriculture, the grain areas where Sunn pest will be fed will shrink, so the density of Sunn pest in the field will decrease.

Figure 6. Plants where Sunn pest' parasitoids are hosted, prairie cress (left) and field daisy (right)

Physical And Mechanical Control

This method was applied in the past years, but has been abandoned for today because it brought some important environmental problems. These applications; It was made by collecting and destroying Sunn pest adults and burning winter site's plants.

Chemical Control

In order to determine the areas where chemical control will be carried out, some counts and evaluations are made in the winter areas and after landing in the Sunn pest fields. As a result of these evaluations, chemical control is decided. In our country, the chemical control the Sunn pest' is 1-3 It is made against the classy nymphs in the period. As a result of field studies (rough, grading, egg parasitoid and nymph surveys), areas with 10 nymphs and more nymphs per m2 are taken into the chemical treatment program.

2. THE GROUND BEETLES [*Zabrus* spp. (Coleoptera: Carabidae)]

Pest Description and Life

Back parts of adults are convex and shiny black in color. There are longitudinal dots and lines on their backs (Figure 6). Adults emerge from the pupae as of May. Adults enter aestivation period in the soil on hot summer days. With the onset of autumn rainfalls, female adults emerge from the soil and lay their eggs in small chambers they open in the soil. The larvae that hatch start damaging the plant. It gives offspring once a year.

Figure 7. Loss of the ground beetles adult (a), larvae (b), damaged field (c) and larvae (d).

The Plants İt Causes Damage and The Type of Damage on The Plant

Wheat, barley, oats and rye are also effective. The damage caused by the ground beetles on the wheat plant occurs in 3 ways depending on the life cycle. It is in the form of young larva, mature larva and adult damage. Young larvae eat the cereal leaves by pulling them into the soil when they find suitable conditions in autumn. Mature larvae cause damage by eating leaves and shoots in the spring. When there is intense damage, gaps occur in the grain field in places (Figure 7).

Adults damage the spike grains in the days close to harvest, and the grains under the sown soil after the cereal planting. The damage to the larvae is particularly related to both soil temperature and humidity and soil structure. Larvae damage decreases in dry years.

Cultural Control With Pests

When wheat or a species other than gramineae preferred by this pest is rotated in the same field for several years in a row, it causes both an increase in insect density and an increase in the damage to the wheat plant. Therefore, due importance should be given to the crop rotation. If the fallowed fields are plowed deeply and weeds are destroyed, the insect damage is further reduced. Thus, many larvae and pupae are destroyed during cultivated since the food source in the field will be removed. The longer the grains remain in the field after ripening, the higher the rate of seed spillage during harvest. This will encourage the reproduction of the pest as it will create an abundant food source for adults and future larvae. Therefore, harvesting should be done without delay.

Chemical Control

The most effective chemical control against the ground beetle is seed spraying. For this reason, in areas where pests are known to exist, the seed should be planted in the soil after duly sprayed. However, in cases where it is necessary, surface spraying may also be recommended in order to partially prevent damage.

3. WHEAT CHAFERS [*Anisoplia* spp. (Col.:Rutelidae)]

Pest Description and Life

Wheat chafers (*Anisoplia* spp.), 10-15 mm in length, usually the head is black and the body is metallic brown (Figure 8).

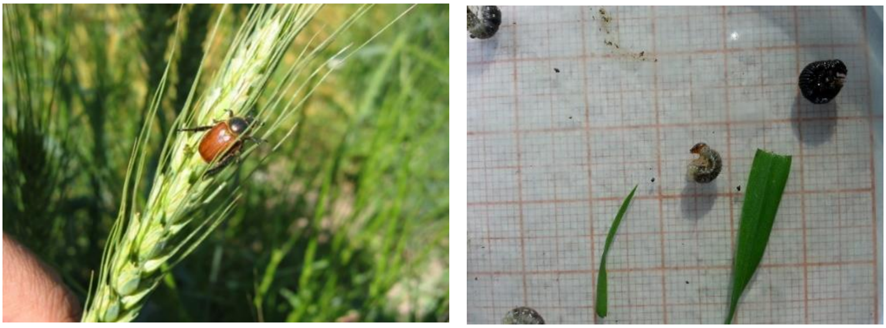

Figure 8. Wheat chafers (*Anisoplia* spp.)adult (left) and larva (right)

Adults are seen on the ears during the ripening stage of the grain. After the adults have been fed for a while, they mate and lay eggs. The hatched larvae cause damage by eating the root system of the early grains. The larvae that hatch cause damage by eating the root system of the grains that develop in the early period. The pest gives offspring every two years. Its larvae are manas type, brown head and soft body. Wheat, barley, oats and rye, as well as many small-grain cereals and many other wild graminae species are the hosts of this pest. Natural enemy is *Machimus anulipes* Brulle as adult predator in our country. (Diptera: Asilidae) species.

The Plants İt Causes Damage and The Type of Damage on The Plant

Larvae are pest by eating the root of the young grain under the ground, but the greater damage to the plant is done by adults. They cause damage by eating the grains in the spike during the ripening stage. Kernels eaten by wheat chafers adults are neither used as seeds nor can they be used for bread making because the core of the grain is eaten.

When 3-4 adults per square meter can cause economic damage. Our country is common in all grain areas.

Larvae are very close to the surface and mobile in the spring months when the soil moisture is high. On the contrary, it is known that the movements of the larvae slow down and go deeper in the summer when the soil moisture is low. Both adults and larvae cause damage to wheat.

Culturel Control

Application of cultural measures significantly reduces the pest population. Very good results are obtained when alternation is applied well. Particularly, plant species belonging to umbelliferae and legumes (leguminaceae) should be included because it is known that the larvae do not feed at all on these cultivated plants. Sowing seeds at an early time, planting early growing wheat varieties and not delaying the harvest give good results. Early and deep plowing of the stubble in autumn or spring to destroy the larvae, untreated soil should not be left at the edges of the field. Soil preparation should be done well before planting. Irrigation adversely affects the development of eggs and larvae.

Chemical Control

It is applied by seed spraying against larvae and surface spraying against adults.

4. CEREAL LEAF MİNER [*Syringopais temperatella* (Led.), (Lepidoptera: Scythridae)]

Pest Description and Life

The upper wings of the cereal leaf miner male butterfly are covered with golden-yellow scales. The lower wings are dirty gray, the edges are gray and with a lot of hair. Viewed from above while the insect is resting, the tips of the rear wings are inverted (V) like a dovetail (Figures 9 and 10).


Figure 9. Cereal leaf miner butterfly (left), damage caused by its larva on wheat leaf (right)

There is a brownish black band at the end of the upper wings of the female butterfly. Cereal leaf miner butterflies are usually seen in May, depending on climatic conditions. Females lay their eggs in clusters in cracks in the soil. The larvae hatched within two weeks enter diapause at 15-20 cm soil depth. After the first rains in autumn, the larvae become active and feed for about 2 months. The pest gives 1 offspring per year.

Figure 10. The larva of the cereal leaf miner inside the leaf (left) and the damage sign and the damaged field (right)

In the years when November-December precipitation is high, larvae density is high, If the rainfall is not sufficient during this period, It was determined that the density remained low even if there was sufficient rainfall in later periods.

The Plants it causes damage and the type of damage on the plant

The host crops of the cereal leaf miner are wheat, barley and oats. In addition; Weeds such as Jointed goatgrass (*Aegilops cylindrica* Host.), Field bindweed (*Convolvulus arvensis* L.), Quack grass (*Elymus repens* (L.) Gould), Charlock (*Sinapis arvensis* L.) and Meadow salsify (*Tragopogon pratensis* L.) are other host plants of the cereal leaf miner. Larvae do the damage. The larvae eat the green tissue between the two epidermis of the grain leaves, causing the leaf to dry from the tip (Figure

10). In a field that has been damaged widely, there is a general lightening of the color and remotely gives the feeling of shooting simoon. It has been determined that in the rainy months of the autumn and the dry months of the spring, they cause significant yield loss in the grain fields.

Figure 11. Cereal leaf miner larva and larval parasitoid *Bracon* (Habrobracon) *stabilis* (Wesmael, 1838) (Anonymous, 2021)

Natural Enemies

As the parasitoid of the larvae of the cereal leaf miner in the cereal areas of the Southeastern Anatolia Region, *Bracon stabilis* Wesmael and *Apanteles* sp. (Hym.: Braconidae) (Figure 11) species were determined, while *Pnigalio pectinornis* L. species was determined in the Aegean Region. In addition, it has been observed that the larvae of the cereal leaf miner, which passes from plant to plant and throw itself into the soil, are hunted by ants, spiders and birds.

Culturel Control

Deep tillage (1-2 times 15-20 cm) in the soil after harvest also helps the death of the cereal leaf miner larvae that have entered diapause and the population of these larvae to decrease. Cereals should not be planted in fields contaminated with Cereal leaf miner for at least two years, It should alternate with anchor plants such as legume, millet and watermelon. Damage decreases in irrigated fields. For this reason, the damage of the cereal leaf miner to the plant can be prevented by watering the cereals in dry years.

Chemical Control

The most suitable period in the pesticide control with the cereal leaf miner is when the larvae feeding in the grain leaves are 2-6 mm in length. It is possible to start chemical control in some regions from March but this situation is closely related with the phenology of the plant and the biology of the pest. Due to the late development of cereals, especially in high and mountainous areas, the chemical control time may be until mid-May. Chemical control can be applied both as early stage spraying (larvae length 2.5–4 mm) and as late stage spraying when larval lengths are 7–10 mm (if the spraying is delayed for various reasons).

5. THE CEREAL WEEVİL, [*Pachytychius hordei* (Brulle) (Coleoptera: Curculionidae)]

Pest Description and Life

The cereal weevil adolescent is 3-4 mm tall and Brown and the front of the back is dark brown. The head has taken elongated after the compound eyes. and the head has taken the form of a proboscis. The pest spends the winter season mature in the soil. After the second half of March where total rainfall exceeds 10 mm and in this period (8-10 days) after the days when the average temperature is above 10 ° C, adults begin to emerge from the soil. After mating, adults lay eggs, the eggs hatch in 11-15 days depending on the climatic conditions. The larvae feed in the grain during the ripening stage and dough stage (Figure 12).

Figure 12. Cereal weevil adult (left), damage caused to wheat leaf (right)

The Plants it causes damage and the type of damage on the plant

It is fed on wheat, barley, rye, oats and Jointed goatgrass (*Aegilops cylindrica* Host.). It does its damage in adult and larval stages. Adults emerging from the soil during the tillering period of the grain; It feeds on the leaves, stems and ears of cereals. When the leaf blade is curved around its axis, as a result of feeding the insect, holes occur in the leaf. These holes appear in the form of parallel lines in the leaf blade and characteristic feeding holes in each row with the development of the leaf and the development of the surface (Figure 12). As a result of the adult feeding on the ears, the number and weight of the grain decreases. The main damage is caused by the larvae. As a result of the grains turning into empty glume by emptying the grains during the ripening and dough stages, it causes product losses. the larvae leave the grain and fall to the soil. Pupa occurs in the nest in the soil. The pest gives 1 offspring per year.

Cultural Control

In places where irrigation is possible, hoe cultivation plants should be planted. In areas that cannot be irrigated, it should be alternated with cultivated plants that do not have hosts. Wheat and barley harvest should be done without delay and grain loss as a result of falling into the field during harvest should be minimal. Fallow application and deep plowing of the soil are beneficial.

Chemical Control

When adults first appeared, the phenology of the cereals should be followed. Against the cereal weevil beetle that comes out of the soil gradually, chemical application should be started approximately 10 days after the exit (jointing stage). At the end of the jointing stage of the cereals and while the spike is in the flag leaf, spraying should be discontinued during this period as adults begin to lay eggs.

6. WHEAT STEM SAWFLY [*Cephus pygmeus, Trachelus tabidus, T. libanensis* (Hym.: Cephidae)]

Pest Description and Life

It spends the winter as mature larvae in the cocoon on the parts of the straws close to the ground. Adults usually come to nature during the jointing stage and heading stages (April and May) of the grains. After a while, adults who feed on the nectar and pollen of weeds mate and females usually lay their eggs one in the internodes at the bottom of the grain ear (Figure 13). The pest gives offspring once a year.

Figure 13. Wheat stem sawfly larva damaging the wheat inside the wheat stalk

The Plants it causes damage and the type of damage on the plant

Damage is caused by larvae that feed on the stem. By destroying conduction tissues as a result of nutrition, they disrupt the carbohydrate and water transport system in the plant. So the grains grow less and as a result, grain loss occurs in cereals. Wheat kernels obtained from the ears of plants affected by insects, it has been observed that they are lighter than undamaged wheat kernels. Also, the stems cut by the larvae, It breaks and falls before harvest and causes grain losses.

Cultural Control

In order to adversely affect adult exits in the next year, the remaining wheat stalks from the stubble should be mixed with the soil and the soil should be plowed deeply. In years when there is no snowfall and the spring is less rainy, the soil should be cultivated with the tools that will leave the stems on the surface. Sowing plants that are known to be non-host of wheat stem sawfly, adversely affects the pest population. The elimination of weeds on the edge of the field is a measure to reduce density. Wheat varieties such as Triticum durum that are resistant to a certain degree of harmful effects should be selected. Where the pest population is found to be potential danger and The fields should not be irrigated because this increases the pest population. It is beneficial to graze the stubble in autumn or spring in order to reduce the Wheat stem sawfly population. It is known that early sowing and early harvest reduce the damage. Any chemical control is not recommended.

7. **APHİDS** on cereals planted in summer and winter months

The important types of aphids that cause grain damage are:

[Russian wheat aphid *Diuraphis noxia* (Kurdjumov), Corn leaf aphid *Rhopalosiphum maidis* (Fitch, 1856), The bird cherry-oat aphid *Rhopalosiphum padi* (Linnaeus), Greenbugs, *Schizaphis graminum*

(Rondani), The rose-grain aphid, *Metopolophium dirhodum* (Walker), The green peach aphid *Myzus persicae* (Sulzer) (Hemiptera: Aphididae)]

Pest Description and Life

Although the colors vary according to the species, the colors of the adults are generally in shades of yellow and green. Their length is between 1.5-3.0 mm. In places where the winter is cold, they spend the winter in the egg period. In places where the winter is mild, they breed all year round without fertilization. It has both winged and wingless forms.

Figure 14. Aphids on wheat leaves

The Plants it causes damage and the type of damage on the plant

Wheat, barley, paddy, rye, oats, and corn are the main host crops. The adults and nymphs of the aphids form large colonies in the leaves and ears of wheat, and the individuals in these colonies do harm by sucking the plant sap. As a result of the insect's sucking, the plant weakens, development stops, and the grain is prevented from maturing, causing it to wrinkle and dry. The yield of the product decreases, its quality deteriorates and the plant dries up. Because of the poisonous substances they secrete during their feeding, they cause abnormal growth and deformations in plants and consequently prevent the development of wheat. Generally, the deformity is seen with the curl of the leaves. Aphids cause the transmission of many plant virus diseases to cereals by carrying and transmitting viruses. With the sweetish substances they secrete, fungi that cause fumajin on the plant develop and prevent the plant from digestion and respiration.

Cultural Control

After the harvest, the field should be plowed and the weed in the field should be chemical weeding. Considering the habitats and reproduction conditions of aphids, precautions should be taken to prevent their reproduction. For this purpose, the weeds in the field should be destroyed, in-field drainage should be done well, soil plowing should be taken care of, plants contaminated with pests should be destroyed, frequent planting and unnecessary watering should be avoided, field leveling should be done well before planting. Rapid colonization of the winged form of the aphids increases rapidly in conditions such as often brittle, water stressed, over-irrigated, moist and low temperature. Therefore, excessive nitrogen use, frequent and excessive irrigation should be avoided. Approximately 10-15 days after aphid colonization, the nymphs of natural enemies belonging to the families Coccinellidae, Chrysopidae and Syrphidae become intensely active, and the insects belonging to these families feed on aphids over these colonies and natural balance is achieved automatically.

Biological Control

The natural enemy complex, which is common in wheat cultivated areas, puts the pest population under high pressure. For this reason, agricultural spraying should be avoided in wheat fields where beneficials are concentrated.

Chemical Control

As a result of the counts in the wheat fields, the harmful and beneficial density per plant is found. Field surveys are done 1-2 times a week. Considering the field survey results regarding the density of aphids and natural enemies, It is decided whether or not to struggle within the framework of the cooperation between Research Institutes and Provincial Directorates of Agriculture and Forestry.

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CHAPTER 10

BARLEY *(Hordeum vulgare* L.) CULTIVATION AND MAJOR FUNGAL DISEASES IN TURKEY

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INTRODUCTION

All over the World, the human population is increasing faster than ever before, and it is expected that by 2050 the world population will exceed 9.7 billion (Anonymous, 2021a), and our country's population exceeds 105 million (Anonymous, 2021b). One way to ensure the balanced nutrition of the population and prevent food crises that may be encountered soon is to increase human food and animal feed production. Barley (*Hordeum vulgare* L.) is deemed one of the first plant species to be domesticated by humankind (Smith and Nesbitt, 1995), and to meet this need is one of the critical crops. While it was a more commonly consumed plant as human food in the early stage of domestication, its use as animal feed has increased over time. Its cultivation continues to play an essential role in modern agriculture today (Harwood, 2019).

Table 1: World barley production and major producer countries (Anonymous, 2021c)

Countrie	**2011**	**2012**	**201**	**2014**	**2015**	**2016**	**2017**	**201**	**2019**	**2020**
European	53.3	52	54.7	59.5	60.5	61.4	59.3	58.6	56	63.2
Russia	8.4	16.9	14	15.4	20	17.1	17.5	20.2	16.7	19.9
Canada	7.6	7.9	8	10.2	7.1	8.3	8.8	7.9	8.4	10.4
Australia	8	8.2	7.5	9.2	8.6	9	13.5	8.9	7.6	9
Ukraine	8.5	9.1	6.9	7.6	9.4	8.7	9.9	8.7	7.6	9.5
Turkey	**7.3**	**7.6**	**7.1**	**7.9**	**6.3**	**8**	**6.7**	**7.1**	**7**	**7.9**
Argentina	3	4.1	5.2	4.7	2.9	4.9	3.3	3.7	5.1	3.8
Kazakhsta	1.3	2.6	1.5	2.5	2.4	2.7	3.2	3.3	4	3.8
United	3.9	3.4	4.8	4.7	4	4.8	4.4	3.1	3.3	3.8
Other	23	21.9	21.4	23.2	22.9	24.9	21.9	23.5	22.3	25.6
World	**124.**	**133.**	**131**	**144.**	**144.**	**149.**	**148.**	**145**	**139.**	**156.**

Barley is the fourth most widely grown grain in the world after corn, wheat, and rice and can be grown all over the World except in tropical areas (Olgun et al., 2013). In 2020, 156.6 million tons of barley production was realized in 51.8 million ha all over the world, while the mean grain yield was 3.02 t ha^{-1} (Anonymous, 2021a). Turkey is one of the world's significant barley producers (Table 1), with 8.3 million tons produced in the planting area of 3.1 million ha in the same year (Anonymous, 2021b). Most of the crop is for animal feed, and only 0.6 million tons of this production is suitable for malt production. Besides, its use as a functional food is gradually increasing due to its content of dietary fibers, proteins, β-glucan, and arabinoxylan, which positively affect human health (Baik and Ulrich, 2008; Köten et al., 2013). Barley's mean grain yield of the unit area was realized 2.68 t ha^{-1} in Turkey (Anonymous, 2021d). This figure is less than 13% of the World's mean, which was about 3.02 t ha^{-1}.

Figure 1. Barley (*Hordeum Vulgare* L.)

Cultivated barley is a plant adapted to a broader range and more resistant to environmental conditions than other grains. It could plant from the poles to the equator in the tropics during spring and summer. It is grown in low and medium altitudes in tropical and subtropical latitudes in autumn and winter. Barley is usually grown two different sowing times that winter and spring-sown. The spring-sown barley varieties are more prevalent than winter in the world, and most of the world's barley production comes from spring barley varieties. However, if the environment is suitable, winter barley varieties are preferred because of yield advantage. Spring barley cultivars are generally known to adapt to different regions widely and do not need vernalization. However, winter barleys need vernalization and can, in general, withstand environments with temperatures of up to -20 °C. Turkey is under the influence of different climates and precipitation (Figure 2). The places where barley farming is mostly carried out are Central Anatolia and Transition Regions, which show arid and semi-arid climates characteristics (Olgun et al., 2013; Sönmez and Yüksel, 2019). Also, barley cultivation is carried out in the Eastern and Southeastern Anatolia Regions and the coastal zone. In Turkey is generally cultivated winter type barley which autumn sown.

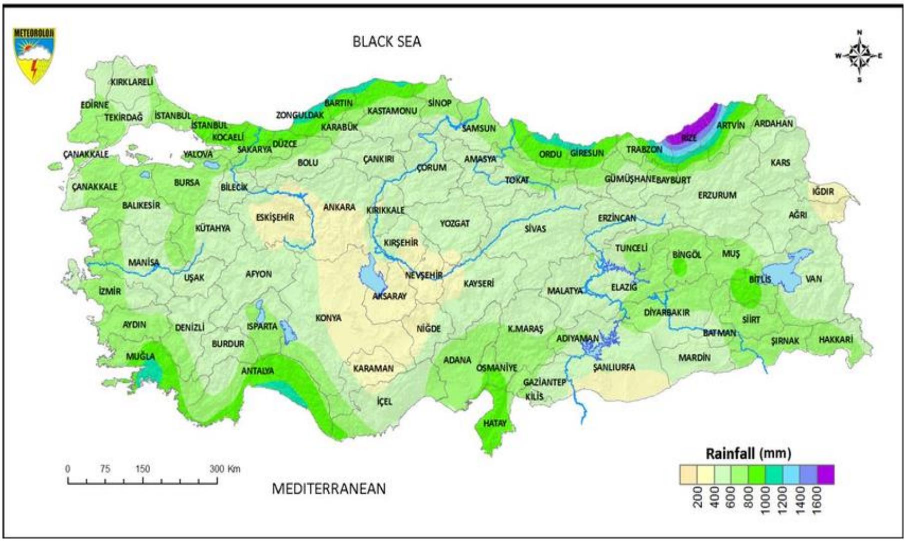

Figure 2. Turkey's of areal annual precipitation (Şensoy et al., 2008)

Barley is relatively cold tolerant and considered the most drought, alkaline, and salt-tolerant among small grain but is not well adapted to wet and acidic soil conditions (Munns and Tester 2008). Thanks to rapid emergence, early maturing, and good efficiency of using water are the vital factors that enable adaptation to drought and high-temperature conditions. Since Barley matures earlier than wheat, barley cultivation is increasing gradually as the first product in irrigated areas where two crops can be grown per year (Öztürk et al., 2017). It is a suitable environment for high-performance where well-drained fertile loamy soils with moderate rainfall (400–800 mm) and temperatures (15–30 °C).

Owing to pasture areas' insufficiency and the insufficient production of raw materials, a significant part of animal feed is met by foreign purchases in Turkey. 3.9 billion USD was paid for the animal feed raw material import in 2018 (Özkan, 2020). Barley is one of the most convenient plants for Turkey to increase animal feed raw material. Because of located in a fertile crescent, Turkey is considered one of the essential barley regions in evolution and domestication. Therefore a large number of wild forms of Barley grow naturally in many regions of Turkey. Due to having a rich gene pool, Turkey has crucial advantages in barley breeding. In recent years, many new barley varieties were developed by breeding institutes and release to the met need of barley seed with different properties in Turkey's different regions (Öztürk et al., 2017; Kendal et al., 2019; Sönmez and Yuksel, 2019). The use of high-yielding, high-quality, biotic, and abiotic stress-resistant varieties that can adapt to different climate types and the complete application of optimum breeding techniques is crucial to increase barley production. It is known that obtaining a high yield per unit area is associated with some plant yield components and varies significantly according to agronomic practices. Barley leaf diseases cause significant decreases in yield in all areas where barley is cultivated, and at the same time, reduces the quality (Oğuz and Karakaya, 2021). And the root rot diseases are crucial biotic stress factors that decrease yield in barley (Hekimhan et al., 2017; Ozturk et al., 2017). For this reason, the recognition of these diseases and the determination of the control methods are of critical importance in increasing barley production in our country.

This study aims to draw attention to the importance of barley cultivation in Turkey and give information about one of the most critical factors that decrease barley production in recent years, barley leaf and root rot diseases, and combatting ways. In this way, a contribution will be made to increasing barley production.

Barley Net Blotch (*Pyrenophora teres* Drechsler)

Identification

The net blotch disease in barley is an essential foliar fungal disease in the world. It causes a significant decrease in yield and quality (Usta et al., 2014; Oğuz and Karakaya, 2017; Öztürk et al., 2017; Saraç et al., 2019). The name of the pathojen of the disease is *Pyrenophora teres* Drechsler [anamorph: *Drechslera teres* (Sacc.) Shoem.]. It has two morphologically different forms. The first is the net form is name *Pyrenophora teres f. teres* of net blotch consist of thin, dark brown, longitudinal streaks on leaves. The second is the spot form is name *Pyrenophora teres f. maculata*, of net blotch, consist of small necrotic spots surrounded by chlorosis (McLean et al., 2009; Liu et al., 2011). According to Oğuz et al. (2019) *Pyrenophora teres f. maculata* was found more prevalent than *P. teres f. teres* in Turkey. They reported that were obtained 109 (62.2%) *P. teres f. maculata* and 66 (37.8%) *P. teres f. teres* isolates where the majority of the samples were taken from Central and Southeast Anatolia regions of Turkey. The disease has been widespread in the Marmara, Aegean, Central Anatolia, Black Sea, and Southeastern Anatolia Regions since 2009 and may cause yield losses of up to 40% in heavy rainy years (Anonymous, 2021f). Damgacı (2014), in his study on barley fields, the average rate of the pathogen was 80.2% in the Trakya region; 51.2% in the Aegean region; he reported that it has a prevalence of 44.4% in the Black Sea region and 41.4% in the Mediterranean region. The researcher also stated that there are areas contaminated with the disease at an average rate of 14.3% in the Central Anatolia region and 12.9% in the South Marmara region. Accordingly, it has been concluded that the most favorable conditions for the development of the disease are found in the Trakya region, as well as in the coastal and passage regions. Considering the five-year survey data, it was concluded that approximately half of all barley cultivation areas are contaminated with barley net blotch disease (Damgacı, 2014). It has been reported that barley net blotch disease causes an average of 23.3% damage in yield (Damgacı, 2014).

Symptoms

P. teres, usually infects and causes disease all part of barley plants which on leaves, stems and leaf sheaths (Dikilitaş et al., 2018). There are two sub forms of the disease. The first is net form (Figure 3), the second is also spot form (Figure 4).

Figure 3. The net form (*Pyrenophora teres f. teres*)

The net blotch disease pathogen is *"P. teres f. teres,"* and the symptoms are usually narrow rectangular shaped, dark brown colored transverse and longitudinal cross capillary lines giving a characteristic network appearance. Spores of the disease are release by splash and infect plant leaves. The lesions on the leaves are in the form of brown stripes and spots. The disease agent spreads to the whole leaf in the form of a net.

Figure 4. The spot form (*Pyrenophora teres f. maculata*)

The pathogen's spot form is "*P. teres f. maculata*," and its symptoms are dark brown, round, or elliptical stains caused by varying thickness surrounded by a chlorotic or necrotic halo. (Figure 4). Its lesions are more oval in appearance. Leaves often have yellowing associated with all of these lesions, especially when the symptoms are severe. The spike can also be affected, and made dark brown spotting and striping.

Life Cycle

Both forms of barley net blotch are classified as stubble-borne diseases since the fungus usually produces the ascocarp as an over-seasoning structure on infected barley debris left after harvest (Liu et al., 2011). *P. teres* is a heterothallic fungus, and two mating types are required for sexual reproduction. Seed-borne mycelium makes up infects the coleoptile, and the first leaf becomes infected. These spores on the first leaf spread the pathogen to other leaves and surrounding plants. Strong air currents release conidia, causing re-infection. Although the entrance is possible into stomata, the initial insertion is done by the enzymatic hydrolysis of the cuticle and cell wall and the pressure generated from the appressoria. Trash and crop debris provide a much higher inoculum level to the pathogen (Figure 5).

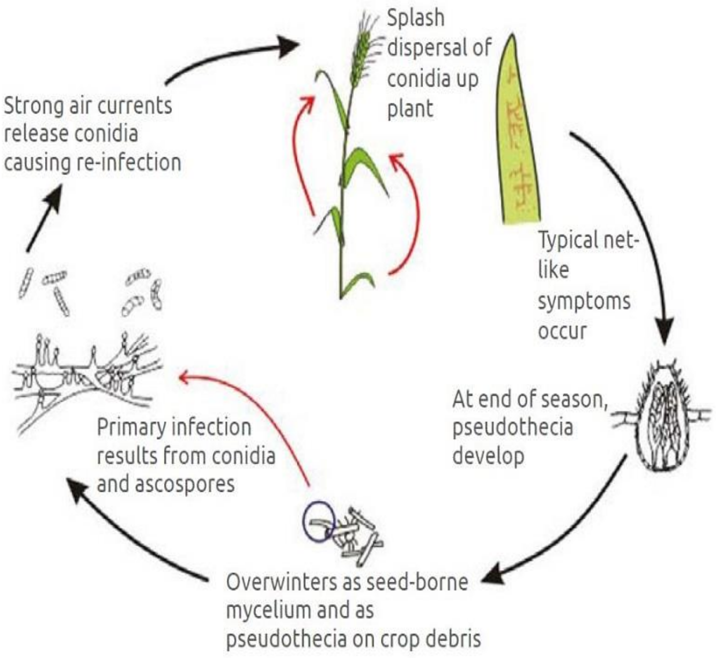

Figure 5. Life cycle of *Pyrenophora teres* (Anonymous, 2021g)

Control

Using barley varieties which has resistant the disease is an effective way of controlling the net blotch diseases (Oğuz and Karakaya., 2017). It has been reported that cleaning the plant residues after harvest and applying crop rotation are effective methods in reducing the spread of this disease (Damgacı, 2004). It is also recommended to use certified seeds or seed spraying wit fungicide. Sowing should not be done frequent, nitrogen fertilizer should not be used more than necessary (Anonymous, 2021e). Chemical control or use of fungicide are not recommended for combatting this disease.

Barley Leaf Scald

Identification

Leaf scald is a fungal disease caused by *Rhynchosporium commune* Zaffarano, McDonald, and Linde [formerly *Rhynchosporium secalis* (Oudem.) J.J. Davis] that attacks the leaves of the plant (Azamparsa and Karakaya, 2020). The disease also known as leaf blotch or scald, affects plant growth and accordingly yield in barley (Kavak and Katırcıoğlu, 1998; Hekimhan et al., 2017). It may cause crucial yield losses if it reaches the upper parts of the plant. It is one of the most destructive barley diseases, especially in areas with a cool and temperate climate (Düşünceli et al., 2008). It affects the growth and yield factors by decreasing the photosynthesis capacity in barley. It also reduces the number of tillering and thousand of grain weight in plants. Although it changes over the years, it causes a significant amount of product loss in almost every region of our country (Oğuz and Karakaya, 2017; Öztürk et al., 2017; Oğuz et al., 2021). As of 2018, barley leaf scald disease caused by *R. commune* pathogen in barley in the Aksaray region was the most common disease (Eğilmez et al., 2019). Erturk et al. (2018) reported that this disease has a prevalence of 4.17% in Eskişehir province of Turkey. Çelik and Karakaya (2015) reported *R.commune* in 108 barley fields out of 121 inspected fields, and the mean prevalence of scald was found as 22.07%. Irregularities in the precipitation regime in the past decade in our country have a negative impact on agricultural production. The shift of rainfall towards spring has increased the effect and intensity of leaf scald diseases in barley (Anonymous 2021e).

Symptoms

The disease's symptoms are mostly seen on the leaves but can also be seen in the sheath, nodes, stem, and ears. The first infections start on the leaves close to the soil, usually in the parts where the leaf blade and the sheath are connected. The spots, which can be 1–2 cm long, are gray-green-bluish oval and irregularly oily spots, and as the season progresses, the middle part of the stain becomes whitish- gray and the edges dark brown (Figure 6). In some cases, before these greasy spots, the leaves are pale, the leaf surface turns greenish off-white, and then necrotic spots occur. It reduces the number of tillering and thousand grain weight in plants. Low temperature increases the damage of the disease more in rainy and foggy weather. The occurrence of these symptoms may vary according to the barley genotype and the isolate of the pathogen.

Figure 6. Barley scald (*Rhynchosporium commune* Zaffarano, McDonald, and Linde)

Life Cycle

Autumn-sown plants can become infected quickly after sowing. The pathogen spreads substantially by rain splash however can spread by air-borne spores also. Their micelles are colorless to light gray, with a diameter of 0.6-3.0 µm. The hyphae are slightly flattened under the cuticle and appear as an oval in cross-section. These hyphae's stroma is seen as thick, short, wide, and several layers of hyphae cells. Conidies without conidiophores develops on very short stems from stroma cells. Conids are colorless, single-chambered, between cylindrical and oval, and with a scythe-shaped bend in their upper cells. It spends the winter on infected dead leaves and plants debris. Under cool and rainy climate conditions, abundant conidia can develop on the leaves' spots in the spring. These conids can be spread around by wind and rain. The disease enters the plant directly from the cuticles of young leaves. With the mycelial development under the cuticle, the cuticle is disintegrated and the conidies formed are scattered around. In this way, new lesions are formed, and in these lesions, abundant conidia may develop. Under suitable conditions, it can also infect the gulls and grains. It is reported that it can infect many plants except barley.

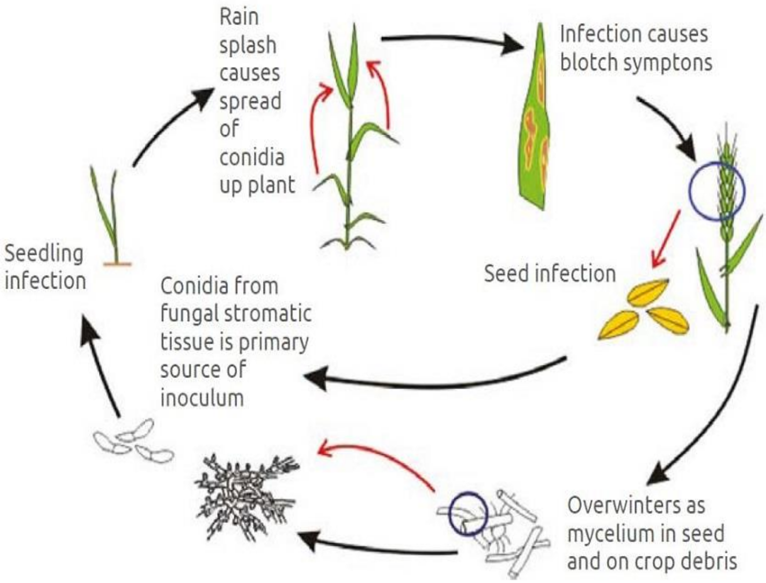

Figure 7. Life cycle of *Rhynchosporium commune* (Anonymous, 2021g)

Control

The most effective method against barley leaf scald is the use of resistant varieties and crop rotation. The disease agent can survive on plant residues and stubble that remain in the soil for two years. Growing barley in a row increases the damage of the disease. Frequent sowing should be avoided, and more nitrogenous fertilizer should not be given to the plant (Anonymous, 2021e). Elimination of primary inoculum sources such as plant residues and diseased seeds is also critical in controlling it. Plant residues can be destroyed by rotation, deep plowing, or burning with plants that are not susceptible to disease. Chemical control can be done as seed spraying and green parts spraying. Although it has been proven that spraying the drug on the leaves is effective in green parts spraying, its use in large areas is not economical and practical. The disease should be monitored well in the field, and fungicide should be applied when the first signs of the disease begin to appear. Generally, spraying prevents the development of the disease, but if the climatic conditions suitable for the development of the disease continue and there is a possibility of an epidemic, it can be recommended to apply again (Anonymous, 2021f).

Barley Leaf Stripe

Identification

The disease is one of the most crucial seed-borne diseases of barley. It is a fungal disease, and its pathogen is *Pyrenophora graminea* [anamorph: *Drechslera graminea*]. Barley striped leaf spot disease is one of the essential diseases seen in winter barley cultivation areas in our country and causes economic losses at different levels (Öztürk et al., 2017). When the climatic conditions are suitable, it can be seen quite widely in the barley cultivation of the Central Anatolia region in rainy years. It can cause product loss between 10-15% (Mamluk et al., 1997; Akan et al., 2006; Ulus and Karakaya, 2007; Akci et al., 2017; Anonymous, 2021e).

Symptoms

The disease causes long brown lines on the leaves (Figure 8). The stripes are usually pale green at first, turn yellow and eventually turn dark brown. Usually, all leaves of affected plants show these symptoms, and some leaves split along strips, giving the leaf a fragmented look.

Figure 8. Barley leaf stripe (*Pyrenophora graminea* [anamorph: *Drechslera graminea]*)

Leaves dry along these lines and tear at these points. Symptoms can be seen from the end of tillering to the maturation period and usually most prominent at spike emergence. When the plant is shortened in sick plants, growth retardation, and early-stage disease in dry farming areas, they can completely dry out. In diseased plants, the spikes dry before they can come out of the sheath, or the sheaths grow in half, in which the bones are curved, and the grains are not fully mature.

Life Cycle

The fungus is present on the seed surface as mycelium and produces spores on the stripes. Barley striped leaf spot cannot survive on host plant residues; mycelium is transported in the seed, the shell, and the pericarp. The agent is carried from one season to the next by the mycelium in the infected seed or by conidiospores contaminated on the seed during threshing. In order for spores to infect flowers, the wind is also required as well as appropriate humidity. In turf infection, cool and moist soil conditions are favorable for infection. Penetration occurs through coleoptile, and the mycelium that develops in the coleoptile systemically develops in the stem and causes symptoms on the stems and leaves. Abundant conidia occur in places where symptoms of the disease are seen. Conidia formation usually occurs at the time of spike and flowering. The culture and wild barley genotypes is he most important host for the pathogen.

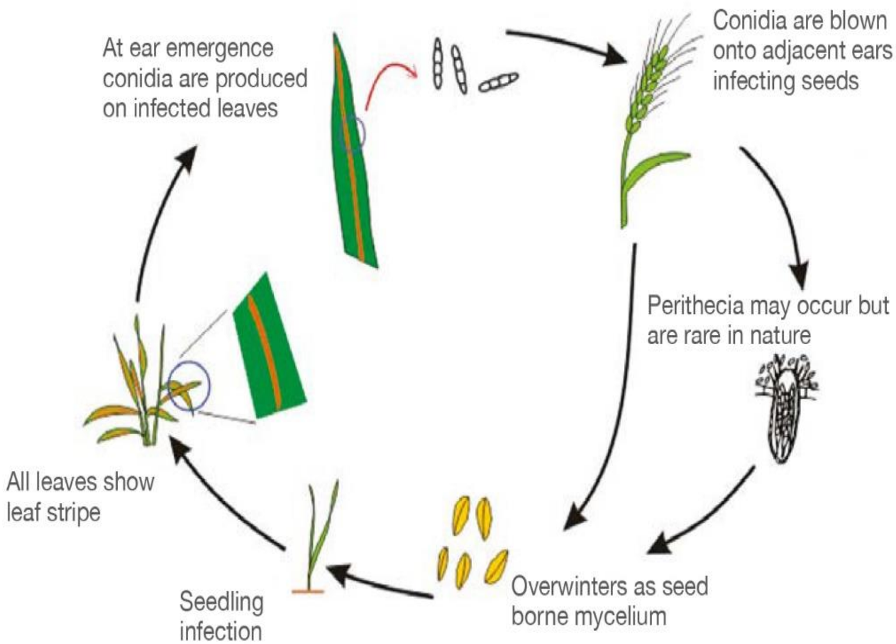

Figure 9. Life cycle of *Pyrenophora graminea* (Anonymous, 2021g)

Control

The most effective methods of combating barley leaf stripe disease are the use of disease-free certified seeds, crop rotation, and the use of resistant varieties. The destruction of primary inoculum sources such as post-harvest plant residue and diseased seed is also very important in controlling this disease. Plant residues can be destroyed by rotation, deep plowing, or burning with plants that are not susceptible to disease. Also, destroying their contaminated barley and some grass species may be effective in lowering the disease's initial inoculum level. It is not recommended for chemical control during the vegetation period with this disease. It is recommended to apply seed spraying before planting (Anonymous 2021f).

Powdery Mildew

Identifications

The pathogen of the disease is a fungus named *Blumeria graminis f. hordei*. Especially in regions where barley cultivation has done irrigated, it causes more damage to the crop than other regions. It causes significant economic losses in regions with mild climates and high rainfall, such as Thrace, Marmara, Aegean, and Mediterranean regions (Öztürk et al., 2017; Ertürk et al., 2018; Saraç et al., 2019). Apart from barley, it also causes significant yield losses in other cool-climate cereals (Ersoy, 2018).

Symptoms

Symptoms of powdery mildew disease can be found in all parts of plants, such as leaves, stems, and spikes, but leaves are the most commonly infected. It begins to appear by forming white-gray pustules on the lower leaves of the barley plant (Figure 10). If conditions continue to be favorable, these pustules expand and reach the plant's stem and upper leaves and even the spike. The micelle layer, which forms a superficial layer on the plant, can be dispersed by wind or precipitation. Yellowing and then necroses occur in the diseased areas of the plant. As the photosynthesis capacity decreases in the diseased plants, the tendency to lie increases, and the yield obtained decreases.

Figure 10. Powdery mildew (*Pyrenophora graminea*)

Life Cycle

Blumeria graminis f. hordei is one of the most common barley pathogens that can be easily spread by wind (Dreiseitl and Kosman 2013). It spends the winter in autumn crops and plant residues as mycelium. In the spring, it starts to infect with conidia and ascospores. The pathogen grows and multiplies in the epidermis cells of young plants. Reproduction occurs through conidiaphores. Conidia place itself on the host and mature between seven and ten days (Ridout et al., 2006). It is commonly seen in temperate regions, and the severity of the disease is predicted to increase depending on climatic conditions (Manning and von Tiedemann 1995).

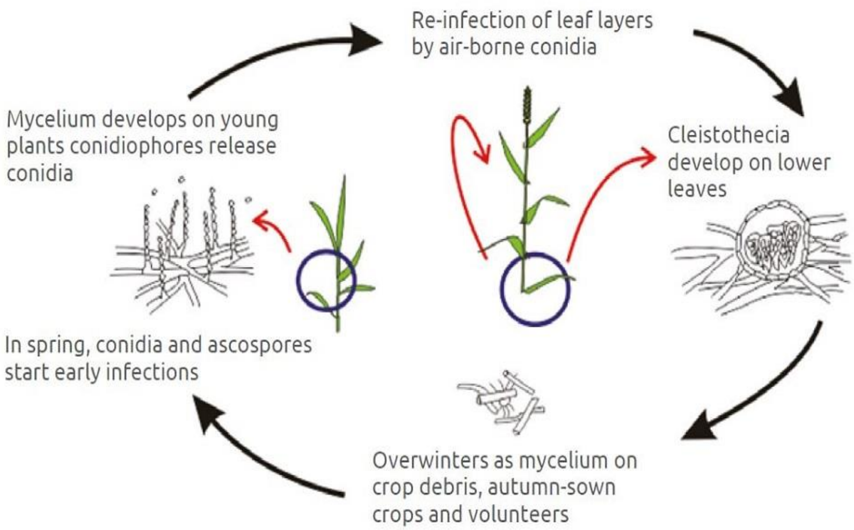

Figure 11. Life cycle of *Blumeria graminis f. hordei* (Anonymous, 2021g)

Control

High sowing density and the use of excess nitrogenous fertilizers should be avoided. Powdery mildew is a disease that can be seen every year according to the conditions. Therefore, the course of the disease should be followed carefully. If the disease continues to spread to the upper leaves, the green parts of the plant should be covered with an appropriate dose of fungicide so that it does not reach the flag leaf. Spraying should be done so that the lower and upper surfaces of the leaves are covered with the pesticide.

Barley Common Root Rot

Identification

Root rot diseases in Turkey in the grain planting area is one of the fungal diseases that cause significant yield losses (Bağcı et al., 2010; Hekimhan et al., 2017; Ozturk et al., 2017). Since the root system of barley is more robust than other cereals, it is less affected by root diseases than others. It has been determined that causes the mean 12% yield loss in barley (Hekimhan et al., 2005). The agents that make up common root rot disease are generally one or not a few but a complex group agent. Different compositions can be seen in different areas, while an agent is dominant in one place, the another agent can become dominant in another. Many pathogens can cause this disease, but the most commons are Bipolaris spp., Fusarium spp., Rhizoctonia spp., Phytium spp., Alternaria spp., Cladosporium spp., Arthrium spp., Chaetomium spp. (Hekimhan, 2010; Dolar et al., 2019; Eğilmez and Boyraz , 2019; Gentosh et al., 2020).

Symptoms

Figure 12. Common root rot (Anonymous, 2021h)

The pathogens are caused brown lesions on leaves nearest soil extending to the stem. The lesions lie down extend in stripes on the root, root collar, and stem of the plants. Due to the water stress experienced during the flowering period, White spike formation and premature death are observed in plants. Water and nutrient transport cannot be provided in plants, and physiological disorders occur. Plants die when the disease is very severe.

Life Cycle

Bipolaris sorokiniana is one of the significant root rot fungi, and the life cycle is given here as an example. It has a broad host potential and is effective in most cereals (Hekimhan, 2010). It is a saprophyte and remain as conidia. The sexual stage is not essential. The pathogen perennates both externally as conidia and inside as mycelium in the seeds, in infected crop residues, volunteer plants, secondary hosts, and free dormant conidia in the soil (Acharya et al., 2011). With the infected seeds' germination, the causal organism's perennating organs become active and the disease's starting point. It germinates entirely in four hours. Under favorable conditions, hyphae, conidiophores emerging through the stomata they touch the host produces. The resulting Conidiophores a series transmitted to rain splash and wind produces conidia.

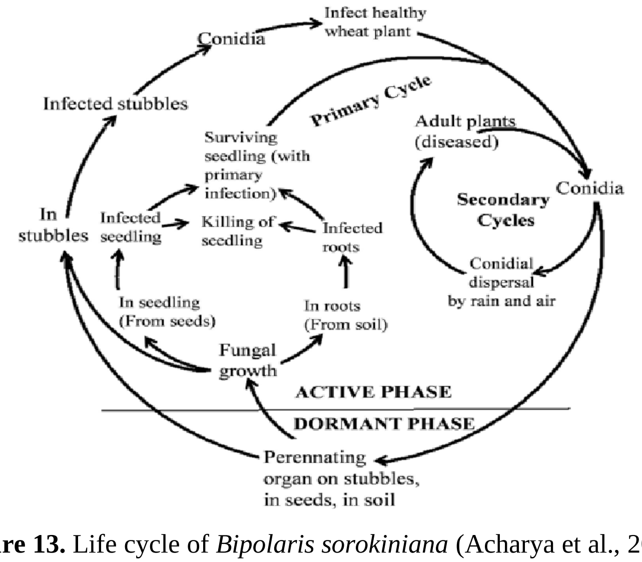

Figure 13. Life cycle of *Bipolaris sorokiniana* (Acharya et al., 2011)

Control

The crop rotation system to be applied between barley and other crops is crucial for thriving agriculture. It is perhaps the most critical tool for farmers to reduce the impact of root and root collar diseases (Bağcı et al., 2010). Also, the other two effective methods for combat this disease are using certified seeds and resistant varieties. The destruction of plant debris at post-harvest plant residue is also significant in controlling this disease. Plant residues can be destroyed by deep plowing or burning. Seed spraying used to combat other barley diseases reduces the disease severity of these pathogens. Also, during the vegetation period, the disease can be chemically combated using appropriate fungicides (Anonymous, 2021g).

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CHAPTER 11

GENERAL SITUATION OF THE LAST DECADE OF TURKEY'S BARLEY CULTIVATION, PROBLEMS AND SOLUTIONS

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INTRODUCTION

In our country, barley, which is generally used as concentrate feed or directly in animal feeding and partially in malt production, is a grain type that is mainly cultivated in semi-arid areas under rain-based conditions (Kendal et al., 2019). In the Western World, barley, which is primarily cultivated for malt production, is used more as animal feed as it goes to developing countries (Anonymus, 1). Recently, an increase in unit area yield has been achieved with the high yield potential of new varieties developed with intensive breeding studies and the widespread application of advanced cultivation techniques in accordance with the technology (Karahan and Akgun, 2020). However, there have been some fluctuations in yield from year to year due to the drought that occurred in the last decade with global warming and some other limiting factors (Francia et al., 2011).

Barley (*Hordeum vulgare* L.) ranks fourth among the grains cultivated widely in the World (Kilic at al., 2010), and ranks second after bread wheat (*Triticum aestivum* L) among grain types in our country (Kilic, 2014)). Turkey is important for barley grain, because it ranks 6th barley production in in the world (Oral et al., 2019). In our country, the intensive cultivation of barley is influenced by factors such as the widespread breeding of sheep and goat farming, ecological conditions (Oral et al., 2019), an easy and economically grown cereal plant. Furthermore, Turkey is one of the world's most important gene center for the first time accepted that farmed wheat and barley Fertile Crescent in the World (Fertile Crescent) is caused by the presence in the region.

In our country, Hordeum distributions show the many different wild species belonging to the genus and Diyarbakir Çayönü presence of barley in the excavation, were caused on Turkey's barley cultivation and culture is indicative of a significant history and agricultural heritage.

Although many varieties have been developed recently in our country, the yield of per hectar is below the world average. The main reasons for this situation can be listed as follows. Ecological factors (Kilic at al., 2018), narrowing of the genetic pool in breeding studies, insufficiency of technological applications (Oral et al., 2018), wrong variety selection(Kendal et al., 2016), application at the wrong time and way (planting, alternation, spraying, fertilization), unconsciousness of farmers, day-to-day policies can be listed (Kendal et al., 2019). Barley production per unit area in our country may increase partially if solutions can be developed against the above-mentioned reasons.

Barley production in Turkey is carried out in very different geographies. For this reason, there are important differences between regions in terms of both cultivation and production. In one region (in some places in the Eastern Anatolia Region) spring planting is done, while in other regions (Central Anatolia, Thrace, Aegean and Mediterranean Regions, Southeastern Anatolia, part of the Eastern Anatolia Region), winter planting is done. On the Other hand; spring or facultative varieties are grown in some regions and facultative or winter varieties in other regions (Kendal et al., 2016). The difference in development between the regions, the level of awareness of the farmers, the existence of small cattle in the regions, the change of the feed factories according to the regions, the number and stable of the varieties developed by the regions have a great effect on the barley production of the regions (Ilgun et al., 2016).

In Turkey, the development of stable varieties due to increasing genetic diversity, especially in support of inputs imported by the state, region and ecological preference of suitable types according to factors and planting, raising awareness of farmers, carried out in accordance with the technology of cultivation practices and product prices caught up in politics of if it is attention to the warranty issue as to ensure the continuity both the production per unit area and the product value of barley will reach the pre-determined level (Anonymus, 1).

1. Barley area, production and improved varieties in the last decade in Turkey

Statistical data related to Turkey's barley are given in Table 1. Statistical data related to Turkey's barley until 2005, did not fully reflect reality.

Table 1. The statistical data related to barley in the last decade of Turkey

Years	**Area sown (ha)**	**Produc-tion (Tonnes)**	**Grain Yield (/ton/ha)**	**Exports (Tonnes)**	%	**Imports (Tonnes)**	%	**Animal feed (Tonnes)**	%	**Industrial use (Tonnes)**	%	**Sertified Seed use (Tonnes)**	**%**	**Degree of self-sufficiency (%)**
2019	3 040 000	7 250 000	2.38	295 428	4.1	521 510	7.2	5 956 847	82.2	241 914	3.3	522 388	7.2	94.7
2018	2 868 833	7 600 000	2.65	39 023	0.5	863 442	11.4	6 450 948	84.9	231 422	3.0	484 947	6.4	90.2
2017	2 748 766	7 100 000	2.58	47 856	0.7	208 402	2.9	6 061 132	85.4	230 974	3.3	548 010	7.7	89.2
2016	2 720 510	7 900 000	2.90	21 131	0.3	107 351	1.4	6 007 407	76.0	236 595	3.0	556 717	7.0	106.5
2015	2 787 297	6 300 000	2.26	16 861	0.3	813 577	12.9	6 338 174	100.6	244 036	3.9	557 459	8.8	80.6
2014	2 783 583	8 000 000	2.87	11 467	0.1	171 770	2.1	6 320 378	79.0	242 321	3.0	544 102	6.8	100.8
2013	2 740 052	6 700 000	2.45	8 711	0.1	298 191	4.5	6 243 686	93.2	243 221	3.6	549 753	8.2	91.8
2012	2 424 737	7 100 000	2.93	139 985	2.0	49 523	0.7	5 994 934	84.4	216 769	3.1	573 767	8.1	101.5
2011	2 611 940	7 000 000	2.68	46 210	0.7	60 409	0.9	5 440 443	77.7	223 176	3.2	608 000	8.7	104.7
2010	2 869 072	7 600 000	2.65	783 187	10.3	72 834	1.0	4 556 902	60.0	223 041	2.9	602 000	7.9	122.1

Anonymus, 1. www.tüik.gov.tr/2019

However, with the support given to the lands and the support given to the product and the basin-based production models, the data realized in the last 10 years are real and it is possible to make clearer plans in the light of these statistical data. These statistical data should be well evaluated in order to make a planning about the future of barley. However, it is possible to make more accurate results and plans to consider animal existence and change.

Turkey's barley field ranged between 2 424 737 and 3 040 000 ha of the last 10 years. The highest cultivation area was in 2019, and the lowest cultivation area was in 2012 year (Table 1 and Figure 1).

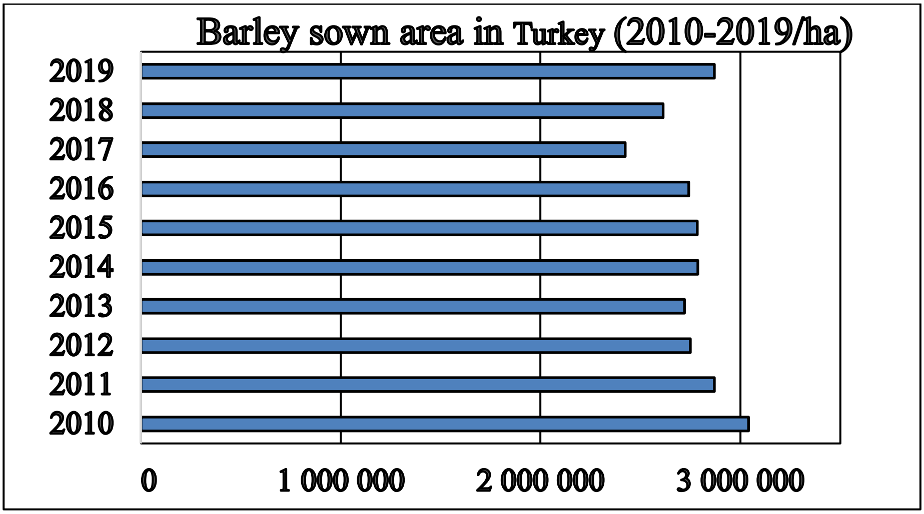


Figure 1. The barley sown area in last decade of Turkey(ha)

The cultivation areas in other years have varied mainly between 2 700 000 and 2 780 000 ha. The cultivation areas are determined by ecological factors and alternating new plants and product price policies, depending on whether farms are satisfied with the barley cultivation in the previous year. In Turkey, because no longer the barley acreage of sown area can not be expanded, therefore it ought to be more efforts to increase the yield per unit area.

Turkey's barley production ranged between 6 300 000 and 8 000 000 tonnes of the last decades. The highest production area was in 2014, and the lowest production area was in 2015 year (Table 1 and Figure 2).

The production areas in other years have varied mainly between 7 000 000 and 7 900 000 tonnes. The production of barley are determined by ecological factors (rainfall days, drought, diseases and practical applications). Turkey in terms of annual barley production is usually self-sufficient state. However, in some years, because of drought and some other unexpected events (low price compared to wheat), the production has partially decreased (Kilic et al., 2010), so import is preferred to close this gap.

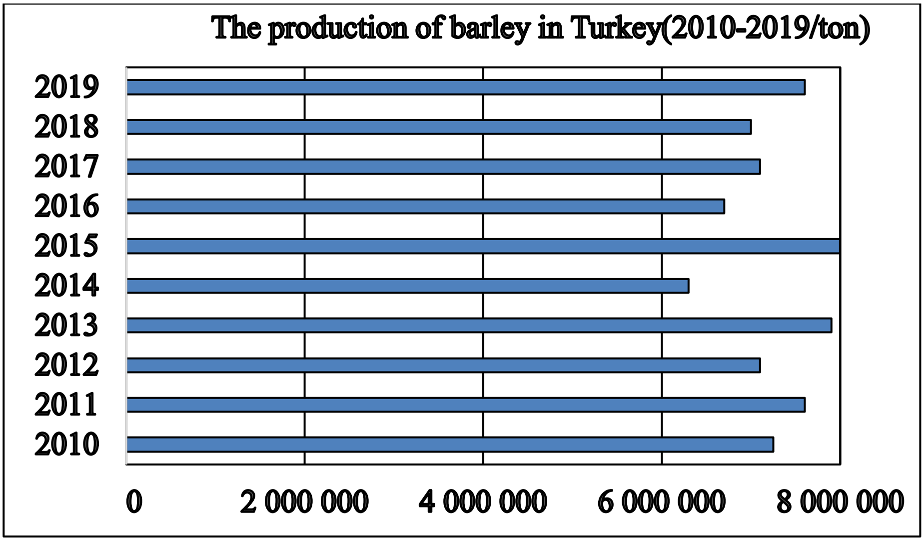


Figure 2. The production of barley in last decade of Turkey (tonnes)

The grain yield of barley per hectar in last decades of Turkey were changed between 2.26-2.93 tonnes, the best grain yield was taken from 2012, while the lowest grain yield was taken from 2015 year (Table 1 and Figure 3).

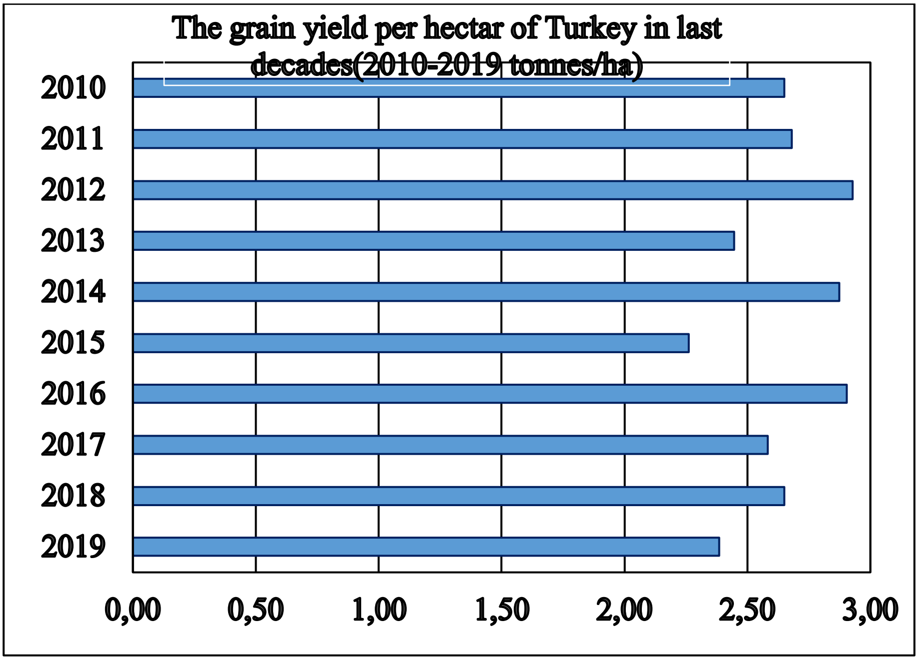


Figure 3. The grain yield of barley in last decade of Turkey (tonnes/ha)

The grain yield of barley in other years have varied mainly between 2.38 to 2.90 tonnes/ha. The grain yield of barley of Turkey is increasing gradually last years (Kaya and Ayrancı, 2016). The grain yield of barley are determined by ecological factors (Kendal and Dogan, 2015) of growing seasons (rainfall days, drought, diseases and practical applications). The grain yield of barley for per hectar is low than mean grain yield of barley of the world. The main reasons for this are; lack of rainfall in barley growing areas (Kilic at al., 2018), very poor soil profile in some places, shortcomings in applications and many other reasons can be counted. Recently, new high-yielding and stable varieties have been developed with breeding studies, but the factors listed above limit the yield (Kendal et al., 2019). Therefore, depending on the changing environmental and climatic conditions, cultivating of varieties which are suitable and stable for sub-regions may partially increase the yield (Kendal et al., 2916).

The exports of barley in last decades of Turkey were changed between 8 711-783 187 tonnes, while the highest exports (10.3%) was made 2010, the lowest export (0.1%) was made in 2013 and 2014 years (Table 1 and Figure 4).

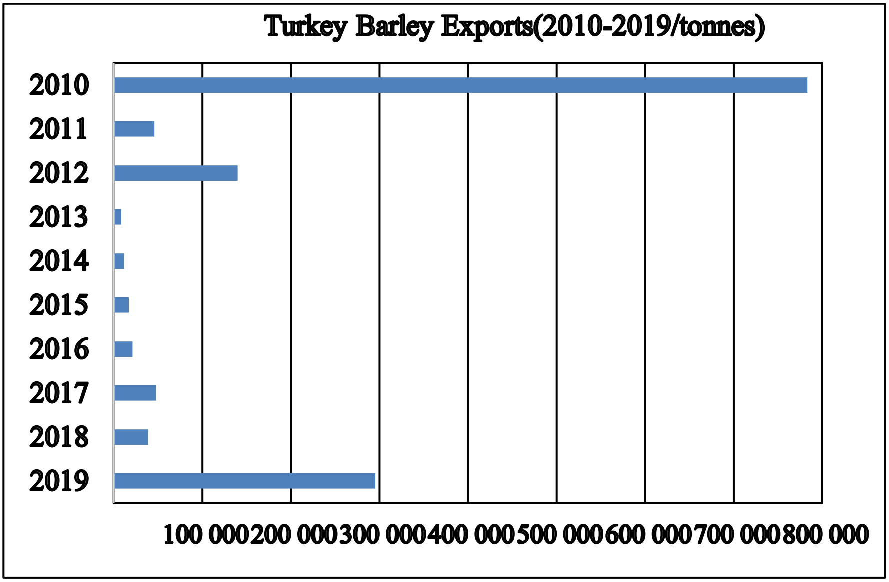


Figure 4. The exports of barley in last decade of Turkey (tonnes)

The exports of barley in other years were changed mainly between 0.3 to 4.0 percent of total production. The exports of barley are mainly determined by production of growing seasons use case in industry and to the existence of small ruminants. Barley is partially exported to other countries in cases where the annual production is high, the use in the industry is low and the small cattle stock is low. Turkey was found in the top 10 exporting countries contain barley, while the majority of exports to North Cyprus, a part of it to Azerbaijan, is a very small amount to other countries (Anonymus, 1).

The imports of barley in last decades of Turkey were changed between 49.523-863. 442 tonnes, while the highest exports (12.9%) was made 2018, the lowest export (0.7%) was made in 2012 years and there was no imports between 2010-2012 three years(Table 1 and Figure 5).

The imports of barley in other years were changed mainly between 0.9% to 11.4% of total production. The imports of barley are mainly determined by production of growing seasons use case in industry and to the existence of small ruminants. Barley is partially imported to other countries in cases where the annual production is low, the use in the industry is high and the small cattle stock is lot. When we keep in mind this data, Turkey imported barley every day of the extent to which we can say now. The main reasons for this can be listed as the increase in feed factories, the increase in the use of barley, the shrinkage of the cultivation areas, and the fluctuations in yield due to ecological factors.

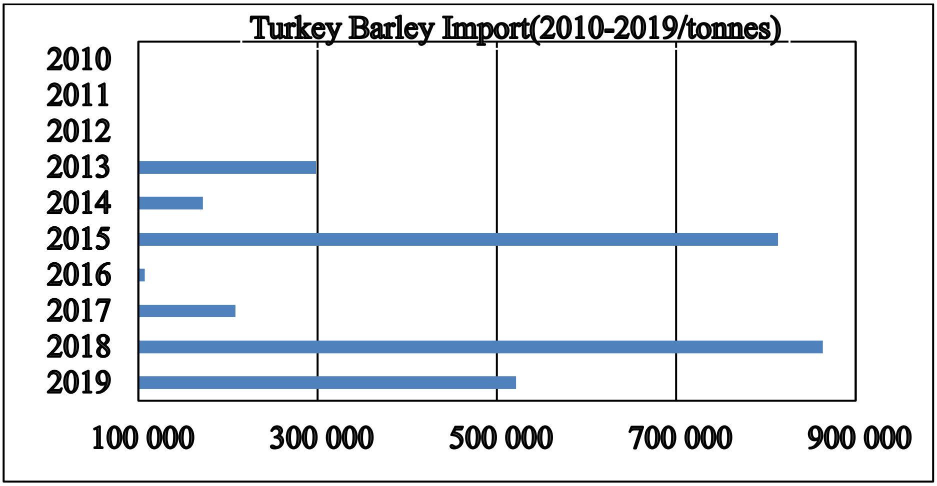


Figure 5. The imports of barley in last decade of Turkey (tonnes)

The consumption amount of barley which used as feeding of animal in last decades of Turkey were changed between 4 556 902-6 450 948 tonnes, while the highest amount of barley which used as feeding of animals (100.6%) was made 2015, the lowest amount of barley which used as feeding of animals (060.0%) was made in 2010 year (Table 1 and Figure 6).

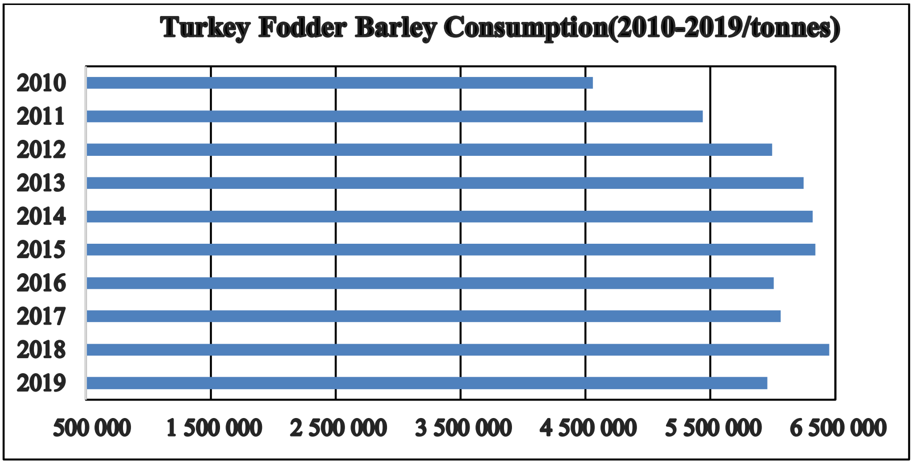


Figure 6. The consumption amount of fodder barley in last decade of Turkey (tonnes)

The consumption of barley for feeding in other years were changed mainly between 77.7% to 93.2% of total production (Kaya ve Ayrancı, 2016). The amount of feeding barley consumption are mainly affected by use case in industry and to the existence of small ruminants. When we keep in mind this data, the consumption barley for feeding every day going to extent, because of the increase in feed factories, the increase in the use of barley.

The amount of industrial barley use in last decades of Turkey were changed between 216 769-244 046 tonnes, while the highest amount of industrial use of barley (3.9%) was made 2015, the lowest amount of industrial use of barley (2.9%) was made in 2010 year (Table 1 and Figure 7).

The amount of industrial barley use in other years were changed mainly between 3.0% to 3.6% of total production. The amount of industrial barley use are mainly affected by use case in industry and to the existence of small ruminants. When we keep in mind this data, the amount of industrial barley use every day going to extent, because of the increase in feed factories, the increase in the use of barley and used of malting in different product (infant formula etc.).

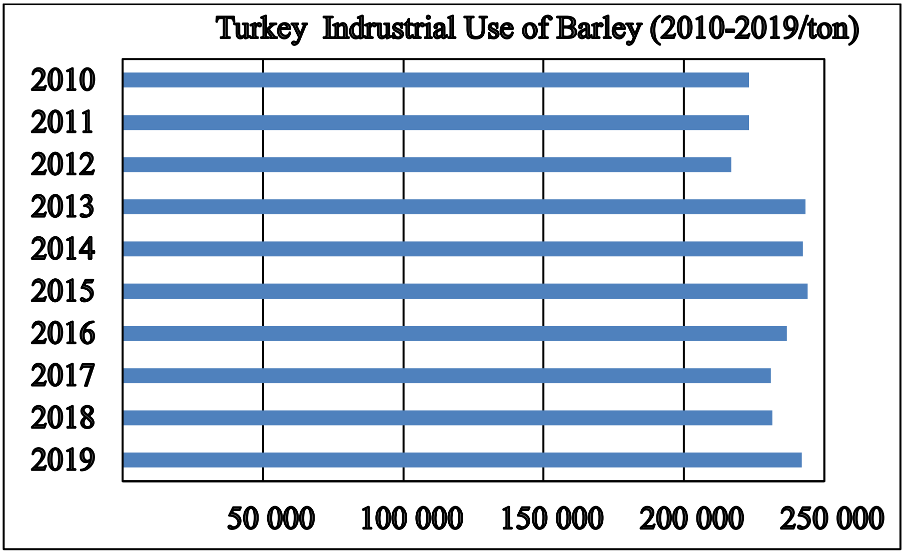


Figure 7. The amount of industrial barley use in last decade of Turkey (tonnes)

The amount of barley seed usage in last decades of Turkey were changed between 484 947-608 000 tonnes, while the highest seed usage of barley (8.8%) was made 2015, the lowest seed usage of barley (6.4%) was made in 2018 year (Table 1 and Figure 8).

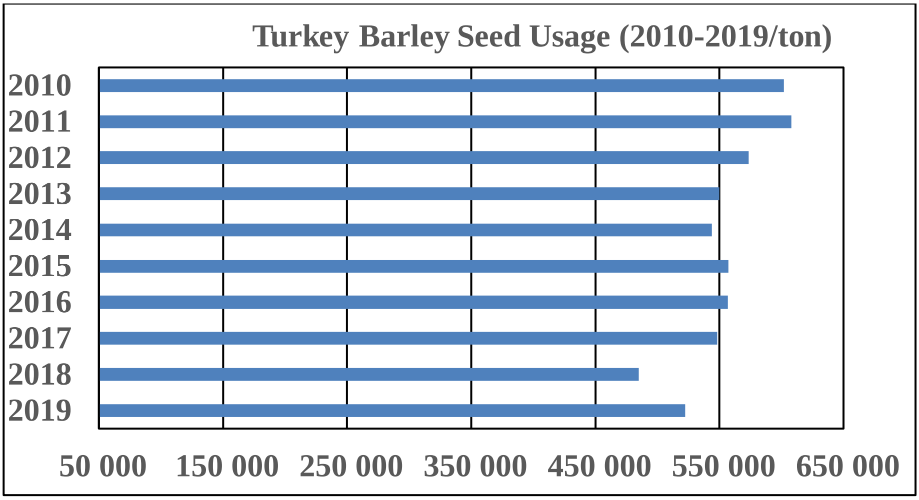


Figure 8. The barley seed usage in last decade of Turkey (tonnes)

The barley seed usage in other years were changed mainly between 6.8% to 8.7% of total production. The barley seed usage are mainly affected by seed price, farmers' experience, seed support, product purchase guarantee, trust in seedlings, etc.. When we keep in mind this data, the seed usage was decreased from 2015 to 2019 years. The reason for the decrease in the use of seeds in the last few years can be explained by the partial decrease of the support given to the use of seeds and the production of their own seeds by farmers. In order to increase the seed amount, the amount of support should be increased, the farmers should be informed, the product purchase guarantee should be given, the seed should be changed more frequently and confidence should be given to the producers. Certified seed is the most basic and important input of the agricultural sector in increasing productivity and production and decreasing production costs. The share of certified seeds in increasing the yield is around 20-30% in self-fertilizing plants such as wheat and barley. For this, the rate of certified seed usage should be increased (Ilgun et al., 2016).

The amount of barley degree of self-sufficiency (%) in last decades of Turkey was changed between 80.6%-122.1%, while the highest self-sufficiency of barley (122.1%) was made 2010, the lowest self-sufficiency of barley (80.6%) was made in 2015 year (Table 1 and Figure 9).

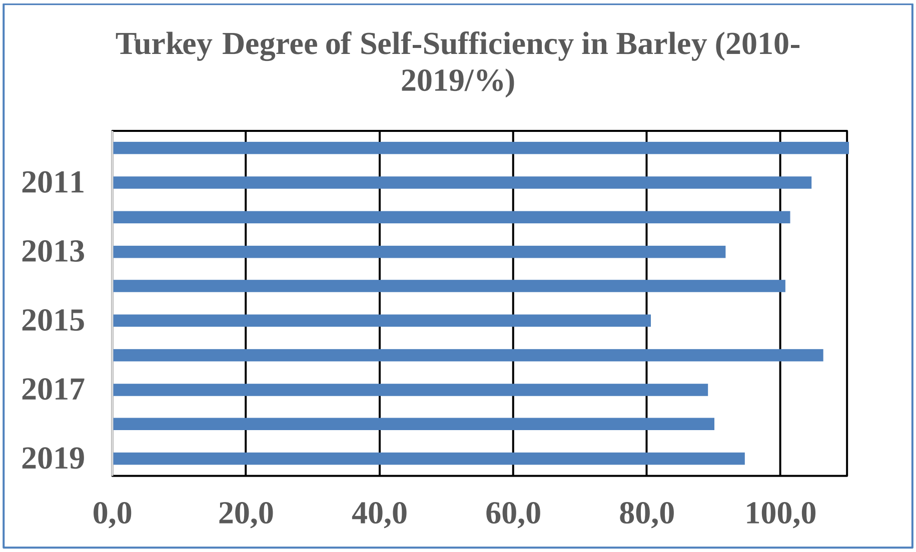


Figure 9. The amount of barley degree of self-sufficiency in last decades of Turkey (%)

The amount of barley degree of self-sufficiency in other years was changed mainly between 89.2% to 106.5% of total production. The amount of barley degree of self-sufficiency are mainly affected by many factors, such as exports, ecological factors, uncertain fluctuations in product prices, supply-demand cycle and the development of the industry., etc.. When we keep in mind this data, the amount production barley of Turkey was enough in some years (2010, 2011, 2012, 2014, 2016) while, it was not enough in some years (2013, 2015, 2017, 2018, 2019). More regular forecasts and strong predictions about barley production and stable policies will increase future self-sufficiency and even ensure surplus production.

The pieces of barley cultivars which registered in last decades of Turkey were changed between 2-21 pieces depend on years, while the highest cultivars (21 pieces) were registered 2018, the lowest cultivars (2 pieces) were registered in 2012 year (Table 2 and Figure 10). There has been a serious increase in the number of registered varieties depending on the years.

A total of 100 varieties have been registered in the last ten years, 45 of them by official institutions and 55 by private sector organizations. On the other hand; many sectors produce by obtaining production permission for the varieties they bring from abroad. For this purposes private sectors got permission 38 varieties, while official sector only got permission 7 varieties in last decades (Table 2 and Figure 10). This rate is increasing day by day (Anonymus, 2).

Table 2. The pieces of barley cultivars which registered in last decades of Turkey

Years	Registered Varieties (number)		Production permitted varieties (number)	
	Official institutions	Private sector	Official institutions	Private sector
2011	4	4		
2012	2	0		
2013	3	5		
2014	4	4		
2015	1	5		
2016	6	1		
2017	3	8	1	1
2018	6	15	4	11
2019	8	6	2	10
2020	8	7	0	16

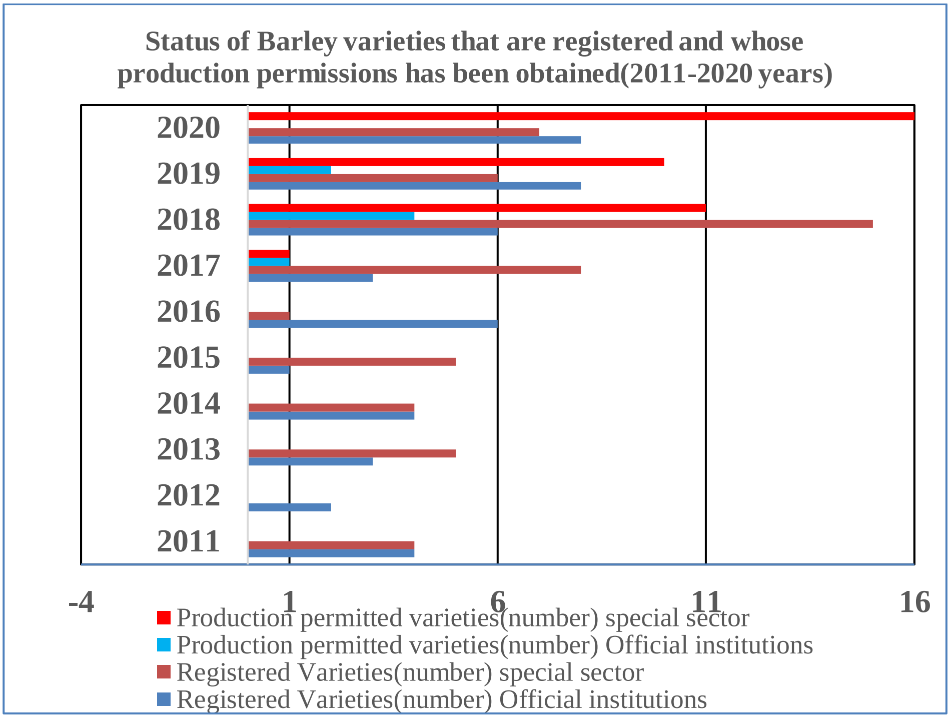


Figure 10. The count of barley cultivars in last decades of Turkey depend on years (2011 to 2020)

2.The Problems and Solutions in Barley Culture in Turkey

2.1. *The problems and solutions related to ecological factors*

Ecological factors limiting the cultivation of certain plants in Turkey (Kizilgeci et al., 2019), as in many parts of the world also has a high impact on barley cultivation (Sabagh et al., 2019; Vaezi et al., 2017). In Turkey, some regions where the cultivation of barley (Central Anatolia, Southeastern Anatolia Region) does not have the amount of rainfall needed for barley(Kilic et al., 2018). In some other regions (Marmara, Western Black Sea), lodging or diseases are increasing due to heavy rainfall. In the Eastern Anatolia Region, frost is frequently observed in barley cultivation due to extreme cold.

The view of barley spike (two rows)

Bird damage causing yield loss in early varieties (Mardin-Kiziltepe)

Development difference view of early and late varieties

Breeding studies

To follow all development periods for high grain yield

Disease in the dry period in tillering time

Therefore, breeding studies need to be done in multiple ways (Dogan et al., 2016). There is a need to develop stable varieties suitable for the conditions of each region and sub-region (Oral et al., 2018). In the last 10 years, considerable progress has been made in this area and approximately 100 varieties have been registered, and this trend is increasing with the private sector also involved (Tablo 1 and Figure 10). Recently, however, as all over the world, in Turkey also developing new varieties with desired properties becomes increasingly difficult due to the narrowing of the gene pool. This unfavorable situation has prompted barley breeders to search differently (Kendal ve ark., 2019), and local barley and wild barley are becoming increasingly important. The use of technology in plant breeding and the development of gene transfer techniques in barley, eliminating the deficiencies of existing varieties, and developing new varieties with desired characteristics appear as promising developments for the future of barley.

2.2. *In barley cultivation, fallow and alternation problems and solutions*

Especially in the Central Anatolia and Southeastern Anatolia Regions where precipitation is less, the preference of cereals per year in alternation limits the yield in barley cultivation due to the lack of rainfall (Kilic et al., 2018). In regions where such problems are experienced, it will be beneficial to apply fallow every two years or use legumes in alternation because it protects and strengthens the soil better in order to overcome these problems.

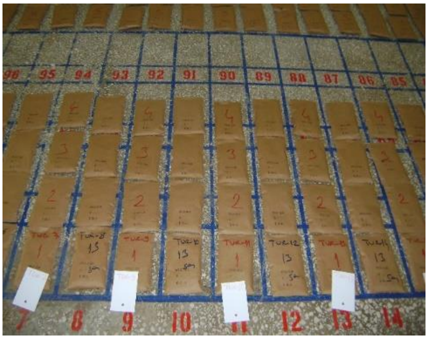
While fallow soil increases the water holding capacity, legumes increase the nitrogen amount of the soil and the water permeability with deep roots. Thus, in order to increase the yield per unit area, both of them are the methods that should be preferred in alternation as they provide a more suitable environment for barley in places where there is insufficient rainfall (Kaya and Ayranca, 2016).

Direct sowing on beds after cotton and corn harvest

2.3. *In the barley cultivation seeding norm problems and solutions*

The cultivation norm in barley may vary depending on many factors. These factors can be listed as follows. The variety feature, cold and frost conditions, early or late sowing, alternation, irrigation and rainfall are the factors that determine the cultivation norm. When the varieties with good tillering feature are grown, less seed amount should be used per unit area, and more seed amount should be used per unit area for varieties with poor tillering. In places such as the Eastern Anatolia Region where the weather is cool and frost events are frequent, more frequent cultivation should be applied, and in the Mediterranean and Aegean Anatolia Regions where frost is not observed then less frequent planting should be applied. In the alternation system, if cereals are continuously planted on top of each other, since the soil is weak, tillering will be less, more seeds per unit area, and if there are legumes in alternation, tillering will increase partially, so less seeds can be used per unit area.

The seed norms should be count for per hectar



The seed of per cultivar should be separate for per parsel

In addition, it is beneficial to make the planting norm more frequently since the tillering will be more frequent in places where rainfall is high and irrigation is performed, and tillering will be less in places where there is less rainfall and irrigation is not done. The application of the planting norm according to the factors specified in barley cultivation both reduces the cost and increases the yield per unit area. Therefore, these factors should be taken into consideration in barley cultivation.

2.4. *Problems and solution suggestions in choice of varieties and use sertificate seeds*

Depending on ecological factors, spring, winter and facultative type cultivars are used in Turkey barley cultivation, because these varieties have three different nature of development. Spring varieties are recommended in temperate regions (Mediterranean, Aegean, Marmara and Southeastern Anatolia), winter varieties in cool regions (Central Anatolia, Eastern Anatolia), facultative varieties in transition regions (West East Anatolia Region, East Aegean Region).

The view of the wrong variety (late and winter) selection for in arid and spring areas

Development difference view of early and late varieties

Because if this rule is not followed, serious yield losses can be experienced in barley cultivation. It is a must to comply with this rule except for some regions with microclimate characteristics. However, despite all the warnings of the breeders, some uninformed farmers sometimes choose the wrong variety. The choosing of winter varieties for temperate regions or vice versa, then serious yield losses occur in production (Anonymus, 1). Sometimes the farmers do not even realize that these yield losses are due to the wrong variety selection. This situation is even worse. When winter varieties are grown in the temperature region, sometimes the growing period is short for these varieties, so these varieties come to harvest before they get spiked, or even before the grains reach sufficient size, and the growing period ends. In the opposite case, spring varieties cannot withstand winter colds and die, because they are sensitive to cold in regions with harsh winter. Therefore, choosing the most suitable varieties for certain climatic conditions will prevent yield losses in Turkey barley cultivation (Kendal, 2015).

Choosing the most suitable varieties (six spike rows)

Choosing the most suitable varieties (two spike rows)

2.5. ***The problems and solution suggestions regarding fertilizer use***

As with other plants in barley production in Turkey, the recommendation of fertilizer without soil analysis and implementation, exactly the unknown fertilizer content, to comply with the fertilizer dosing, use of fertilizer used or the wrong fertilizer type enough at the base, early implementation of high fertilizer, to be administered once or less using excessive amounts and not knowing exactly the types of fertilizers to be applied in top fertilization are among the problems limiting the yield. The solution suggestions for the problems that occur depending on the bottom fertilization and top fertilization differ. The results of the irregular application of fertilization occur in two ways.

First of all, DAP (18-46-0) fertilizer, which is used especially in bottom fertilization, causes excess phosphorus fertilizer to accumulate in the soil. In order to prevent this, the application of 20-20-0 DAP or 15-15-0 compound fertilizers, which are used in annual plants and revealed by research, will partially solve these problems. In addition, the application of the fertilizer applied at the base together with the seed causes the roots to burn or the plant to be stressed during the dry periods when the plant growth is not yet sufficiently developed. Second, the yield is limited due to insufficient nitrogen (N) fertilization used in the bottom and top fertilization.

The wrong use of fertilization

Another problem is the early application of nitrogenous fertilizers applied in top dressing brings along some problems. In order to prevent these problems, top fertilizers should be given as 2 or 3 batches or if they are given as a single batch, they should be delayed a little. In order to eliminate these problems, the relevant sector (farmers and technical staff) should be trained by experts.

2.6. *The problems and solution suggestions related to sowing*

In Turkey, there are a large number of deficiencies related to barley cultivation areas. First of all, sowing time are not known exactly, sowing is done too early or delayed, sowing is carried out before the soil reaches full annealing (muddy or dry), sowing depth cannot be adjusted exactly, second crop areas are not known yet, although there are tools that direct stubble sowing, sown seeds are full the fact that it cannot be closed and the roller is not pulled after planting creates an environment for the decrease in yield. The planting time varies according to the regions. The sowing should be done early (August, September) in regions with harsh winters (Eastern Anatolia, Central Anatolia, Transition Regions), while the sowing should be made late (October, November) in temperate regions (Aegean, Mediterranean, Southeast and Marmara Regions).

Early sowing in temperate regions causes early emergence of plants, and the early start of development prepares the ground for the plants to be damaged by winter cold and late spring cold (Anonymus, 1). Delaying planting in cold regions causes late emergence of plants, and delayed development, this is causes the plants to be damaged by winter frosts. For healthy plant development, it is recommended to planting on time according to the climatic conditions of the regions.

Sowing at the appropriate time with suitable seeding machines

In addition, it is recommended that the planting be done neither in heavy mud nor in dry weather when the soil is damp. After the rotation, especially after the cotton and corn plants, it is recommended to plant with seeders that directly tear the soil and sow the seeds (Kendal et al., 2016).

2.7. *The problems and solution suggestions related to frost and cold damage*

A considerable problem in several areas of Turkey is late spring frost damage of spring type barley in Aegean, Mediterranean, Southeast and Marmara Regions (Kendal et al., 2016). In barley cultivation of center Anatolia and East of Anatolia, the effects of winter frosts are low due to the fact that the plants are at rest during the winter months.

Winter cold damage(Malatya province)

Winter cold damage (Elazığ province)

The view of varieties affected and unaffected by winter frosts side-by-side

Late spring frost damage(Diyarbakir-Hazro)

Late spring frost damage (Diyarbakir-Hazro in 07/April)

Late spring frost damage (Diyarbakir-Hazro in 07/April)

Even if the plants are damaged, they can recover later. However, frosts occurring in late spring have a high effect. Plants are highly damaged in this period as they are in the period of stalking or spitting. Even if the effect of frost passes, these plants cannot recover again and cause high yield losses (Whaley et al., 2004). Generally in spring, the plants continue to develop as the temperature rises throughout the day, sometimes the temperature values suddenly drop at night, or sometimes the temperatures drop locally for a short time (especially in Southeastern Anatolia Region). Even for a short time, late spring frosts occur and cause serious damage (Frederiks et al., 2011) Farmers make some applications (late sowing, late feeding of nitrogenous fertilizers, deep sowing, rolling, choose different varieties) to protect the plants from late spring bars (Asadi et al., 2013). Cold stress can cause late spitting of seedlings injuries due to damage to the spikes, thus decreasing yield and decreasing quality (Andaya and Mackill, 2003), and cold damage can also greatly prevent the growth and reproduction of plants, which can lead to damage to the leaves, and to increase chlorous wounds on the leaf (Mahajan and Tuteja, 2005). The stress caused by late spring frosts causes great changes in the biochemistry and physiology of plants (Berova et al., 2002). In generally; the physiological process due to photosynthesis is highly affected by the late spring frosts, which affects the development of the plant and reduces the efficiency of the plant (Liang et al., 2007).In extremely cold regions, it is necessary to take measures such as early planting of barley, using more seeds per unit area, choosing cold-resistant varieties, making the planting slightly deeper, and using base fertilizer.

2.8. *The problems and solution suggestions related to chemical weed control*

The mistakes made during the weeds in barley cultivation in Turkey can be summarized as follows. Not doing weed control at all, not doing weed control on time, using wrong chemicals, not adjusting chemical doses, being unconscious of the farmers about chemicals, weed gaining resistance against the use of the same drugs, some imported chemicals being inadequate in the fight and expiration. Using chemicals that are out of date brings along problems limiting yield in the region.

Spraying with suitable chemical spraying machines

A poor weed control causes loss of yield in a field

The proposed solutions against errors made during the weeds in barley cultivation in Turkey can be listed as follows. Since chemical control with weeds in the regions increases the cost, especially farmers with small areas often do not struggle to weeds. This situation causes both a decrease in yield and an increase in weed populations. In addition, it can be said that the sowing of the same product group and the transportation of weed seeds that are not in the regions together with the seeds brought from abroad have increased the weed population in the barley areas in the region to region recently.

In the same regions, it is also sometimes done early or late in the struggle against weeds, when it is done early, weeds that come out late reduce the yield, and when it is late, the chemicals used cannot have a fully fatal effect on the weeds, and the weeds that do not die can limit the yield. Another problem is that chemicals used against weeds in the region are used directly in large areas without being tested in the region, it can be said that they are insufficient in weed control. Since most of the farmers engaged in barley cultivation in the region do not have sufficient knowledge and skills about the chemicals used in weed control, they cause damage to the barley plant by using some wrong chemicals against narrow-leaved barley plants, and because they cannot fully adjust the dosage of the chemicals and they are constantly using the same chemicals, they are both foreign. They are insufficient in weed control and also cause some weeds to gain resistance against chemicals. It can be said that some farmers, especially those engaged in small-scale barley cultivation, are insufficient in weed control due to the use of chemicals which stay from the previous year and out of date against weeds.

2.9. ***The problems and solution suggestions related to lodging***.

The lodging limits the yield emerged as a problem in many production barley area of Turkey. The reasons for the problems encountered with lodging can be listed as follows. In Aegean, Mediterranean, Southeast and Marmara Regions, early sowing, continuation of rainfall after filling the barley grain in the development period and storm or wind with precipitation, preferring tall, susceptible varieties or local populations, excessive nitrogen fertilization, excessive irrigation, fallow areas or lentils factors such as barley cultivation after sowing, use of more seeds per unit area, crop cultivation, and not pulling out the roller after planting cause to lodging in barley cultivation in summer regions and thus decrease yield. If the following measures are taken, delaying sowing partially, using spring fertilizer less, adding varieties resistant to bedding, sparse cultivation, not planting barley after lentil in alternation, not using it more than necessary if irrigation is to be done, planting deep into the soil and pulling the roller after planting, it will partially prevent lodging in these areas. Lodging is not seen as an important problem because the lands in the Central Anatolia and Eastern Anatolia region are arid and the rainfall is often low during the development period of barley production.

The view of lodging, because of wrong variety selection

The view of short and long varieties side by side

2.10. *The mistakes during harvest and suggestions for solutions*

During the barley harvest in Turkey, many mistakes are made. We can list them as follows; early harvest for the second crop application in Mediterranean, Southeast and Marmara Regions, delaying harvest due to the inadequacy of harvesting machines in some places, insufficiency of suitable harvesting machines, not giving necessary importance to the barley harvest for to start harvest of the wheat, failure to comply with the appropriate harvest time during the day due to the rush of the combine harvester operators, harvesting at night, fast and high speed, the slope of the fields, the windy weather during the harvest, and the occasional rainfall are the factors limiting the yield of barley. In order to eliminate these problems, the following points should be considered.

A barley field that can be harvested

Harvesting operations performed on parents to develop variety

Not rushing the harvest for the second crop, making the harvest on time without delay, developing suitable harvesting machines, paying more attention to the barley harvest, making the harvest at the appropriate time and speed, not doing the harvest at night, not doing fast and high speed on slopes, pausing the harvest in windy weather, rain If it rained, pausing the harvest for a certain period of time, preventing the mixing of barley with straw in places where the harvest is made in return for straw, will prevent barley loss and partially increase the yield.

The harvest should be done right time

CONCLUSION

In Barley production of Turkey, important problems (errors in alternation, improper fertilizer application, the wrong kind of selection, sowing at the time not right, not right and wrong times made the harvest, improper use of chemicals, frost and cold damage) determined under long-time execution barley breeding projects. Although these problems vary from region to region, they significantly effect the yield. If solutions to these problems identified above can be developed, it is possible to partially increase the unit area grain yield and quality of barley.

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CHAPTER 12

TRITIKALE, BREEDING AND CULTIVATION

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INTRODUCTION

Grains are an important source of protein and energy in the diet of humans and domesticated animals. Increasing alternative food sources is very important both in closing the product gap that can incur as a result of natural disasters (drought, disease and pests) and in countering the food requirement of the increasing world population. Most of the developing countries are trying to increase their wheat, barley and corn production to meet their food and feed needs. Increasing grain production in these countries can be achieved by increasing the average yield per unit area or by planting grain in more marginal areas. In these environmental conditions, it is very important for farmers to be more tolerant of risks and grow crops that will generate more yield. Due to the limitations imposed by intensive farming and possible climatic changes, it will not be easy to increase production to the extent that is needed to feed the increasing world population. Therefore, in the present day, it is necessary to grow plant species in marginal soils that can produce high yields with low input costs. Growing rye and triticale instead of wheat and barley in marginal areas will enable a more economical exploitation of these areas. Yield will increase when wheat and barley are planted into real cultivation areas. The fact that using arable land has been maximized to its limits has made it necessary to introduce new plant species that can produce high yields per unit area, are resistant to biotic and abiotic stress factors, and can be grown in marginal areas.

Soil conditions such as drought, pH level, salinity, lack of trace elements and toxicity are factors limiting grain yield. Compared to commonly grown grains, triticale is an alternative to other grains, especially wheat and barley, which has advantages under such soil conditions. Indeed, triticale has replaced rye and winter barley in saline soils in Belgium.

Studies show that triticale can benefit from the soil better than other grain types such as wheat, barley and oats, and therefore it has been demonstrated that triticale adapts better to slopes than wheat and barley as well as soil depths that are not suitable for wheat farming and arid regions with very harsh winters. In studies conducted in different parts of the world, it has been determined that the yield potential of triticale is superior or similar to small grain kernels.

Triticale is of great importance in regions where annual rainfall is limited and irrigation is not an option because it is more productive than other grain types in arid conditions. It was discovered that triticale developed better than wheat in arid conditions, and was more resistant to diseases such as mold, rust diseases and smut.

Approximately 50% of the total agricultural land in Turkey is dedicated to the production of field crops, the proportion of these grains is approximately 60% while the share of triticale in cultivated areas is only 0.7%. The average yield in the country is 296 kg/da for wheat, 268 kg/da for barley, 283 kg/da for rye, 278 kg/da for oats, while the highest yield is obtained from triticale with 341 kg/da (*TÜİK, 2021*). In our country, the amount of land that is not suitable for the cultivation of many plant species or has been excluded from agriculture due to low yields is very high. Therefore, there is a significant deficit in terms of a balanced diet for humans and the supply of feed for livestock. Under the circumstances, grain has a great potential in closing the deficit in food and animal feed in Turkey as well as in the world. When the suitable parts of unused agricultural land in Turkey are cultivated with triticale, an additional source of income will be generated for the farmers in the region. In addition, triticale is an important plant considering that it will enable the overall reduction of marginal areas in Turkey amounting to approximately 3 million hectares of fallow land when satisfactory yields are obtained. Triticale improvement studies have been initiated in our country to this end and are continuing intensively. In this context, 24 triticale varieties have been registered by the Agricultural Research Institutes and the private sector until 2021. In recent years, the importance of triticale has begun to be understood better and it has been preferred for concentrated feed and roughage production in regions where animal husbandry is widespread. In regions with high altitudes and continental climates, especially in Eastern and Central Anatolia regions, it is important to expand the production of triticale because of its resistance to abiotic stress and its potential to include fallow lands into agricultural activities.

As a result of a study carried out for 10 years in 2 locations with 3 wheat and 1 triticale varieties developed for the Eastern Anatolia Region, it was determined that the grain yield of triticale was 13-17% higher than the yield for wheat varieties (*Küçüközdemir et al., 2020*). In a study conducted by *Çaçan and Kökten (2019)* in Bingöl, the feed properties of bread wheat, barley and triticale varieties were examined and it was concluded that triticale had a higher green and dry grass yield than other grains in addition to having a high crude protein yield. It has been stated that triticale will play an important role in countering the need for feed.

Animal husbandry is of great importance in our country. Feeding is essential for a good livestock potential. Concentrate feed as well as roughage are of great importance in animal nutrition. It is not possible to meet all their nutritional needs only with roughage, since the nutrient needs of both milk cows with high milk yields and animals to be fattened are high. In order to meet the roughage needs of livestock, it is necessary to use roughage as well as concentrate feed. As a matter of fact, concentrate up to 2.5-3% of the feed to be consumed on the basis of dry feed by dairy cattle can be used to feed a cow with a live weight of 100 kg.

Quality feed deficits and balanced nutrition are the leading problems in animal nutrition in our country. The inability to use the available resources efficiently, which can contribute linearly to feed production, has also been seriously effective in the emergence of this problem. Therefore, it is of great importance to include land which has been excluded from agriculture due to low yields. Triticale, which has both high quality roughage and concentrated feed, has the quality to reduce the deficiencies encountered in this area and add important value to intensive (farm model) farming. It constitutes an important material especially in the preparation of rations with high protein and carbohydrate content. Although the amino acids in its composition, mainly lysine, are in the form of a concentrate feed that is close to wheat, it is also valuable in terms of the establishment of artificial pastures created to replace natural pastures that have recently experienced serious quality problems. Triticale also has the ability to create an energy source in feeds. These properties make triticale an alternative feed especially for fattening cattle and poultry. The fact that the cellulosic structure of triticale is relatively low, while polysaccharides such as starch is high, make it suitable for rumen fermentation and facilitated enzymatic evaluation and effective digestibility and consequently profitable livestock breeding and the utilization rate of unit feed in dairy cow farming increases. Thus, the rate of profitability also increases.

Triticale is also a source of feed that can be used in the preparation of balanced rations in terms of minerals and vitamins. It is an important material in countering the needs of young animals and dairy cows, especially calf feeding, with a relatively high ratio of vitamins A, E, K and B-complex, minerals such as P, Mn, Cu, Fe, K, Ca and Mg. Farm animals, whose needs are met with rations of high quality feed, will face fewer problems in terms of reproductive physiology, which directly affects profitability and ensures the continuity of the herd. Especially its vitamin A content significantly reduces the problems that can be encountered in this area. When preparing rations for animals, the protein content and energy level of the rations are very important. Grain kernels hold the most important place among the energy feeds included in animal rations. Grain is both a source of protein as well as energy, especially for monogastric animals. Grain kernels can consist up to 70% of the rations of ruminant animals. An examination of the nutrient composition of cereal grains reveals that the values are of similar value that cannot be distinguished from each other. As a matter of fact, cereal grains contain 8-15% protein, 1-6% fat, and 75-80% carbohydrates. On the other hand, they contain low levels of Ca and high levels of P. All cereal grains are a good source of vitamin E in terms of vitamin content while their B complex vitamins and vitamin D contents are very low.

Triticale will fill an important gap in solving the problem of feeding, namely as both roughage and concentrate feed, which is one of the important problems of our livestock farming that has not developed despite the support provided. Depending on the quality at maturation during the harvest period, the feed value of triticale is equal to or better than corn, wheat barley, rye and sorghum and it can be substituted for maize, wheat, barley, rye and oats in rations. The digestible total energy amount in triticale grain is very close to wheat and corn with 44.2%. Free sugar was determined as 4.3-7.6%, starch as 53-63%, crude fiber as 2.3-3.0% and ash content as 1.8-2.9% (*Varughese et. al., 1996*).

The fact that triticale is suitable for grazing is of great importance in its use as animal feed. In addition to its use for different purposes such as grazing, grass, grass + grain and silage, the availability of summer, alternative and winter triticale varieties increases their cultivation gradually in developed and developing countries. 80% of the total triticale cultivation in the world consists of winter sowing and 20% of summer sowing.

Some triticale varieties can yield economically when they are allowed to grow grains after being grazed once or twice. In studies (*Crespo, 1982; Brown and Almodares, 1976*) it has been determined that the crude protein ratio of triticale grass is equal to rye, wheat and oats, while its cellulose and lignin content is lower than that of rye and wheat. In a grazing study, the live weight gain of animals feeding on triticale was 0.72 kg per day, while animals feeding on wheat gained 0.69 kg and those on rye gained 0.59 kg (*Dodge, 1989*).

When triticale was first discovered, it was intended for human nutrition, but one of the problems the growers encountered in the early years of improvement was the low hectoliter weight due to wrinkly kernels. This decreased the flour yield. However, this problem has been solved to a great extent, thanks to the subsequent improvement studies. The yield and yield components of the newly developed triticale genotypes are higher than the initially developed ones, and plant height is shorter. It has been determined that these improvements have also been achieved in terms of resistance to laying, early maturing and grain shedding.

Low gluten content, low gluten quality and high a-amylase activity reduce the bread quality of triticale. The high α-amylase activity, which is the biggest problem in the use of triticale flour alone in the bread industry, is suitable for malt and yeast production. Triticale generally has a high malt loss but a high malt extract, high diastic strength and high a-b amylase activity. However, preliminary studies carried out in the Eastern Anatolia Agricultural Research Institute revealed that some triticale varieties can be used in bread making and baking flour with appropriate processing techniques (Fig. 1). More studies are needed on this subject.

Figure 1. Breads, cookies etc. made of 100% Ümranhanım triticale flour, 2nd International Conferance on Triticale and Wheat Biology Breeding and Production. 25-28 June 2018, Erzurum, TURKEY (Photo by Ü. Küçüközdemir)

Triticale production in the world will increase if the alternative uses of triticale in human nutrition as well as using it in animal nutrition increases. Triticale will take an important place especially in regions where the agriculture of many plant species is difficult and yields are low due to global climate changes.

BREEDING

Triticale was developed to obtain a new grain type that would combine the superior agro-morphological and quality characteristics of wheat with the resistance of rye to abiotic and biotic stresses. Triticale (x Triticosecale Wittmack) is a man-made, self-pollinating amphidiploid type of grain. Depending on its genetic structure and environmental conditions, it can take some dust (pollen) albeit minimal from the outside. Scottish scientist Stephen Wilson obtained the first triticale in 1873 by pollinating wheat (Triticum) with rye (Secale) pollen. The name triticale is derived from the partial combination of the scientific names of wheat (Triticum) and rye (Secale).

The first triticale plants produced had sterile pollen. Subsequently embryo recovery and colchicine-induced chromosome folding approaches were developed, and triticale breeding became more practical (*Blakeslee ve Avery 1937; Laibach 1925*). In our country, the first triticale studies were initiated by Dr. Osman Tosun in 1940. Today, many breeders in various countries are trying to develop easier and more successful methods in this regard.

All of the triticale hybrids are allopolyploid / amphipolyploid, they have different chromosome structures and ploidy levels. *Simmond* (*1976*) summarized the origins and breeding processes of different types of hybrids in Figure 2.

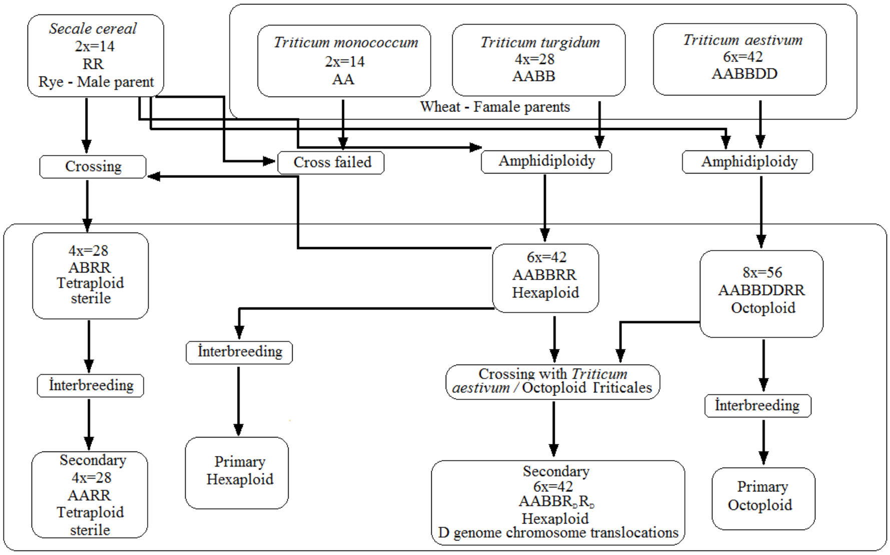

Figure 2. Summary chart of the origins of different types of triticale. (Source: Simmonds 1976)

Triticals are divided into two groups, namely primary and secondary. Triticale obtained from the first hybridization between Wheat (Triticum) and Rye (Secale) which has not been subjected to further cross-breeding are called primary triticale. Primary triticale is divided into hexaploid and octoploid triticale depending on the type of wheat used as the mother. Hexaploid triticale is derived from the hybrid of durum wheat (Triticum turgidum) as mother and rye (Secale cerale) as father (Fig. 3); Octoploid triticale is derived from the hybrid of bread wheat (Triticum aestivum) as mother and rye (Secale cerale) as father (Fig. 4). Octoploid triticale (2n = 8x = 56) are not common, but they are important in obtaining hexaploid triticale.

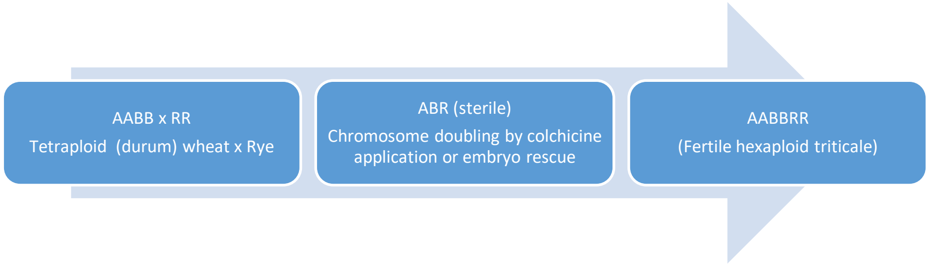

Figure 3. Hexaploid triticale

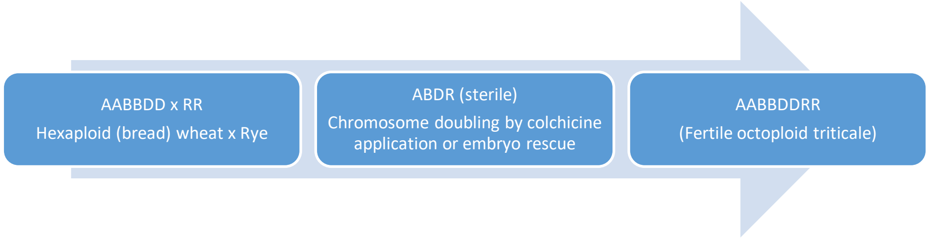

Figure 4. Octoploid triticale

Although octaploid triticale have better end use quality properties compared to hexaploid triticale, they are not preferred due to genetic instability and flower sterility (*Mergoum et al., 2019*). Flower sterility is also a fact for tetraploid triticale. Tetroploid triticale, obtained from crossing rye (RR) with diploid wild wheats (AA, BB, DD) with 2n = 2x = 14 chromosomes and having 2n = 4x = 28 chromosomes (AARR, BBRR, DDRR) after the chromosomes are folded or a mixture of A, B, D and R genomes are sterile triticale (Fig. 2). Since tetroploid triticale was not promising and the desired gene combinations could not be achieved, studies on this subject have been discontinued.

Hexaploid triticale are more stable and fertile than octaploid forms, more showy and have high potential. In addition, the flour of hexaploid forms manifests similar properties as soft wheat flours. Because of these properties, the hexaploid forms have been studied more. Current successful triticale varieties are secondary amphidiploids derived from a hybrid of durum wheat and rye. The high yield of triticale and its adaptation to partially arid regions comes from durum wheat with the A and B genomes, while the low yield but adaptation to extreme conditions comes from rye with the R genome. Triticale is successfully grown in all environments where its parents can grow. While the yield of wheat grown in marginal areas is lower compared to triticale, the yield potential of triticale in optimum growing environments is higher than the yield potential of wheat under the same conditions. When breeders developed primary triticale, they faced many adverse conditions such as partial flower infertility, wrinkled grains, poor agronomic and morphological characteristics, low yield and quality. In order to improve these characteristics, they started backcrossing triticale with wheat as well as crossing different primary triticale with each other. Thus, they obtained secondary triticale containing new combinations of wheat and rye chromosomes (*Mergoum et al. 2009*; *Randhawa et al. 2015*). Commonly used triticale today are those in hexoploid (2n = 6x = 42) form (Figure 3).

Triticale are divided into two as complete and subsitute (substitution) according to the rye chromosomes in their structures. The triticale in which the rye chromosomes remain unchanged are complete triticale and adapt better to marginal agricultural areas. Subsitute triticale have been hybridized with hexaploid triticale (AABBRR), common wheat (AABBDD) or octoploid triticale (AABBDDRR), the R-genome chromosome or a segment of the R-genome chromosome has been substituted with a D-genome chromosome/a segment from the R-genome from bread wheat or octoploid triticale (AABBRDRD) or changed places (AABBDR). The most important discovery occurred when the first subsitute triticale (Armadillo) was selected at CIMMYT in 1967 as a result of natural pollination between a triticale and an unknown Mexican semi-dwarf bread wheat. The translocations that enabled this line pave the way for a good path for breeders to follow in improving the genetics of triticale. Improvements were achieved in terms of quality, wrinkly seeds and flower sterility of new triticales.

Triticale are divided into three categories according to their growing nature as summer, winter and alternative varieties. The vegetation period of summer triticale is short, insensitive to photoperiod, their number of spikelets and tillering capacity is less (*Royo et al. 1995*), they can be grown in temperate regions. Winter triticale have vernalization needs (higher than freezing point but less than 9 °C) that vary between 4-8 weeks. They are photoperiod sensitive and need 12 h / day light (*Mergoum et al. 2004*).

Figure 5. Breeding lines are under snow (Photo by Ü. Küçüközdemir)

Hybridization, pedigree, bulk and single seed selection methods applied in self-fertile species such as wheat and barley are used in triticale breeding. However, there are two issues to be considered in triticale breeding. One of these is that triticale are affected by their wheat and rye genomes when creating phenotypic variations in offspring when they are crossbred among themselves (*Lelley 2006*). Therefore, classical breeders should regulate the balance between wheat and rye genomes in early generations. On the other hand, pure lines are more difficult to obtain as the rate of foreign pollination in triticale is higher. Breeders need to make sure that the lines that they think might be candidates for variety are completely settled (pure). All triticale varieties developed in our country so far have been developed with classical breeding methods (Fig. 6).

Figure 6. Crossing studies (Photo by Ü. Küçüközdemir)

The stages of the studies carried out to develop the triticale varieties are given in Figure 4. These studies are the same for wheat and barley breeding. In this process, the F stages to be pedigreed or bulked vary according to the breeder and the work force. Some breeders make single spike selections (pedigree) from the F3 and / or F5 levels, some from F6, and some from F4 levels every year. An example breeding scheme is given in Fig. 7.

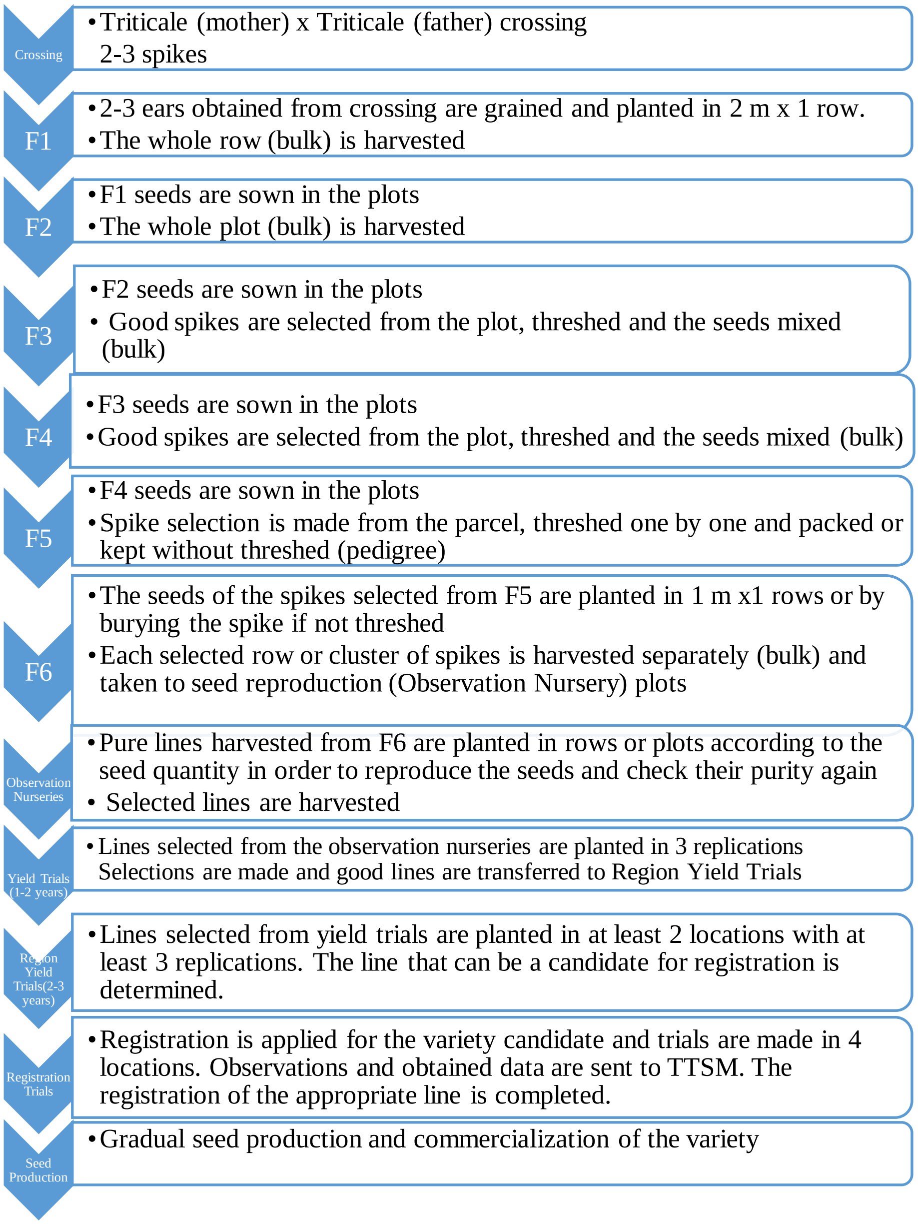

Figure 7. Sample Breeding Scheme (Source: East Anatolia Agricultural Research Institute)

In addition to crossing, selection and introduction methods are also used in triticale breeding. Institutions and organizations working on triticale breeding try to select genotypes suitable for the region they work in by exchanging materials. The genotypes selected as a result of the selections are integrated into the breeding stages according to their purity (Fig. 7) and the selection continues until the registration application (Fig. 8)

Figure 8. Triticale Yield Trials in East Anatolia Agricultural Research Institute (Photo by Ü. Küçüközdemir)

Figure 9. Group of world scientists visiting along with Dr. Ü. Küçüközdemir (triticale breeder) the 2nd International Conferance on Triticale and Wheat Biology Breeding and Production. 25-28 June 2018, Erzurum, TURKEY (Photo by Ü. Küçüközdemir)

Although triticale breeding is generally aimed at animal feeding, it has a high potential to be used in human nutrition. Therefore, it would be appropriate to carry out breeding programs for this purpose as well. Triticale quality breeding strategies can concentrate on: (a) grain for human consumption (demands of large-scale milling industries and bakeries, pasta products, functional foods); (b) grain for animal feed (monogastrics and ruminants); (c) forage (grazing and silage, green-fed, and hay for ruminants); and (d) utilization as an energy crop (mostly bioethanol from grain or full biomass utilization) (*Randhawa et.al.,2015*).

In recent years, in addition to classical breeding studies, biotechnological methods have also been used in breeding studies. These studies should be intensified to shorten the breeding process and obtain pure lines more quickly.

CULTIVATION AND ADAPTATION

When compared with the first years, important developments have been achieved in triticale. Significant progress has been made in increasing the genetic yield potential of triticale. Negative features such as susceptibility to diseases in triticale, plant height, spike infertility, low hectoliter, wrinkly kernels, late maturity in the first years have been significantly corrected with breeding studies. In a study carried out in Erzurum with 14 triticale genotypes for 2 years, the hectoliter weights of the genotypes according to years were determined as 75.20-80.00 kg/hl, 73.20-79.60 kg/hl, respectively; 1000 grain weights were 25.50-33.50 g, 37.50-49.20 g, grain protein ratios were between 13.83-15.20%, 11.28-13.27%, respectively. It is reported that the precipitation especially in June and July 2016 increased the 1000 grain weights and yields however protein ratios decreased (*Küçüközdemir et al., 2018*). In a study in which winter hardiness degrees were determined, 15 triticale genotypes were tested at -17, -19 and -21 °C, Umranhanım variety (60%) and genotype 10 (50%) manifested significant vitality compared to the other genotypes at -21^0 C. (Fig. 10)

Figure 10. Cold hardiness tests in triticale (Photo by H. Karagöz)

Figure 11. Cold tolerant and sensitive varieties in Edirne (Photo by İ. Öztürk)

Triticale is more resistant to biotic and abiotic stress conditions than wheat and barley. However, there are differences between the varieties in terms of tolerance. Winter-resistant varieties are less affected by early spring frosts and cold damages occurring during vegetation. While choosing the variety, the climate and soil structure of the region should be taken into consideration, and the varieties developed for the region should be preferred. Otherwise, stress factors will cause more damage (Fig. 11 ve 12).

Figure 12. Stem and Yellow rusts in wheat (Photo by Orçun Yılmaz)

Triticale is more resistant to biotic and abiotic stress conditions than wheat and barley. Breeding studies for marginal areas (acidic or alkaline soils), lack of trace elements (copper, zinc and magnesium) or trace element excess (boron) and drought stress are the main subjects of many summer and winter triticale development programs in the world. It has been reported that Zn deficiency in soil, which is one of the important factors limiting yield in Konya region affects triticale less than it does wheat, barley and oats (*Bağcı, 2004*).

Planting winter grains is recommended, especially in regions where most of the annual rainfall occurs in autumn and winter. However, low temperatures in the winter months cause winter damage and significantly reduce yield. In these regions, especially barleys are planted in summer due to winter damage. The yield of barley cultivated in dry conditions and in summer is very low. Therefore, if triticale is planted in regions with significant winter damage, both winter damage will be minimized and high yields will be obtained. In addition to all these, it should not be forgotten that triticale is recommended for marginal areas, it should not be preferred in areas where wheat is produced and high yields are achieved.

Figure 10. Ümranhanım Triticale Variety in Erzurum

In addition to all these, it should not be forgotten that triticale is recommended for marginal areas and should not be preferred in areas where wheat can be produced and high yield can be obtained.

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CHAPTER 13

USES AND CONSUMPTION PROBLEMS OF TRITICALE

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INTRODUCTION

Triticale has a unique place among the cereals. Triticale; according to FAO-STAT-2020; is produced in 39 different countries on the world. Poland, Germany, Belarus, France and Hungary are the leading countiries, respectively. China is a top producer outside Europe. Since the first production of triticale, it was used only for animal feeding. However, as a result of further studies, it is becoming widespread that triticale is used in different areas from human nutrition, to feeding different animals or to making bioethanol. Triticale is an important grain in animal nutrition that may be needed to close the for roughage and concentrate feed (Zhu, 2018).

Grain and also grass of triticale have huge potential for animal feding besides cultivated for grazing purposes. Its amount of digestible protein and lysine is higher than wheat and barley. Its grain contains approximately 12-14% protein. The hectoliter weight is 70-75 kg and a thousand grain weight is 34-39 g, and grain shedding problem may be at late harvest. Triticale grain is usually used for poultry feding; feeding quality of grain is equal to that of corn, wheat and barley. Depending on the seasonal conditions and the environments in which it is grown, 3-6 tons of silage yield can be obtained per decare.

Although it varies according to the type of situation its high protein ratio, the triticale has potential for animal use in fodder, silage and grain and behind human diets as a additive cereal in different foods and beverages (Sucu & Çifci, 2016; Zhu, 2018). Triticale has a lot of advantages as a feedstock due to its lower nitrogen (N) requirement at growing, also has a good performance on light soils, and in 2nd/3rd cereal positions in the rotation because of its better take-all resistance. (Davis-Knight and Weightman 2008).

Figure 1. Triticale Spikes before harvest (Photes taken by Emel ÖZER)

A study result by Gozubuyuk et al. (2019) produced energy was used more effectively by 41.8% from triticale when checked to the wheat plant. The most important reason that increases energy efficiency and profitability is the amount of product obtained as a result of production. In order to increase these values, it is necessary to increase seed efficiency and quality values and reduce input rates.

In Turkey last two decades triticale production and attention is growing. Scope of Turkey agricultural basin production and support model Triticale will be supported in many cities (45) and provinces (266) for 2021 growing season. In Turkey triticale is using mostly for animal feding and grazing.

TRITICALE’S NUTRITIONAL CONTENT AND USES AREAS;

-Nutritional Content of Triticale;

Triticale is a grain that combines the yield potential and quality of wheat and rye's tolerance to disease and environmental factors. Triticale combine grain quality with the high protein and lysine levels, also tolerate to common fungal diseases of cereals produced with low input requirements and lower sensitivity to high field capacity and alkaline and acid soils, and lack of nutrients is of a land types that provides a better yield than other cereals. (Ballesteros-Rodríguez et al. 2019 & Bezabih et al. 2019). Triticale is characterised by a high amino acid–lysine content (0.31–0.71 g/100 g) and it allows to gain high fibre content in products because of its high content in the grains (11.7–13.6 g/100 g) (Zhu, 2018-Fra’s et al.2016).

Some triticale varieties have a relatively high concentration of lysine that limited the amino acid of cereals (McGoverin et al., 2011). Triticale nutritional values are widely studied topics include starch, non-starch polysaccharides (e.g., arabinoxylans), polyphenols (e.g., phenolic acids), alkylresorcinols, and vitamins (e.g., vitamin B1) (Buchholz et al., 2012; Rakha et al., 2011). The starch contained in the triticale grain is 60-70% of the grain weight and contains approximately 23 % of amylose and 77 % of amylopectin (Burešová et al., 2010). The average nutritional composition of triticale grains is shown in Table 1. (Burešová et al., 2010) Triticale grain's chemical composition is beneficial for animal digest.

Table 1. Nutritional composition of triticale grains (Average % of dry matter)

Species	Triticale	Species	Triticale
Water (g)	10.01	**Energy(kcal)**	338
Total Protein (%)	10.2-15.6	**Total Lipids (%)**	2.1-2.4
Starch (%)	53-65	**Soluble Sugar (%)**	3.7-7.6
Cellulose (%)	2.3-4.5	**Mineral Salts (%)**	1.4-2.9
Carbohydrate, by difference(g)	73.14	**Fiber, total dietary(g)**	14.6
Calcium (mg)	35	**Magnesium (mg)**	153
Iron (mg)	2.59	**Phosphorus (mg)**	321
Potassium(mg)	466	**Sodium (mg)**	2
Zinc(mg)	2.66	**Vitamin C, total ascorbic asid**	0
Thiamin(mg)	0.378	**Vitamin E(alpha-tocopherol) (mg)**	0.9
Riboflavin(mg)	0.132	**Fatty acids, total saturated(g)**	0.318
Niacin(mg)	2.86	**Fatty acids, total monousaturated(g)**	0.183
Vitamin B-6(mg)	0.403	**Fatty acids, total polyunsaturated(g)**	0.794

The comparative chemical composition and energy value of some cereal grains in Europe is shown in Table 2 (De Boer and Bichel, 1988).

Table 2. Comparative chemical composition and energy value of triticale and other cereals in Europe (g/kg of dry matter)

Indicator	Wheat	Triticale	Rye	Oat
Total proteins	130	140	116	120
Cellulose	23	22	22	55
Starch	680	620	640	440
Sugars	31	55	50	18
Mineral salts	18	20	22	33
Calcium	0.8	0.9	0.9	1.2
Phosphorus	4.0	3.6	3.2	3.8
Energy content (ml/kg of dry substance)				
Ruminants	14	14	13.9	11.5
Poultry	14.8	14.5	12	12.3

Tables 1 and 2 show that the nutrient content of triticale grain is high. In Table 2, it is seen that the energy content of triticale grain is slightly higher for ruminants and poultry compared to other cereals.

Carbohydrates, as the major components of triticale, account for over 70% of the dry weight. In different studies showes different amount of starch contents of triticale grains. Carbohydrates are the largest constituent of triticale, accounting for more than 70% of the dry weight. In studies conducted on this subject, it was determined that triticale grains have different amounts of starch content.

Studies cunducted on this subject have reported the protein content and composition of different triticale lines. Tritical's protein content is heavily affected by environmental conditions (Pattison & Trethowan, 2013). Triticale contained low protein in the endosperm than wheat (Pattison et al. 2014).

Although triticale grain gives values between wheat and rye due to its technological features, however its bakery qualities are low because of poor amount of cellulose (Ittu et al.2014). The insufficient amount and quality of cellulose in triticale seed reduces the usefulness of its products obtained by processing triticale flour for humans and thus reduces its potential profitability (Pattison et all. 2014).

The increase on protein content, balanced by the amino acid composition, advantageously separates triticale grain for peeled grains and food concentrates production (Sucu & Çifci, 2016; Zhu, 2018).

ANIMAL FEEDING

Triticale is grown for grain feed, forage and bioethanol production according to the farmer's needs. The ability to be used for storage by making hay or silage increases the importance of being a feed plant. Some varieties can be used in conjunction with grazing and mowing.

Triticale is most commonly grown on the American continent for fodder, beside in developing countries grains are used for human consumption (Glamoclija et al. 2018).

Breeders have studying on higher protein composition in triticale since last decade. Triticale is source of kind of phenolics with antioxidant activity, alkylresorcinols, phytoestrogens, vitamins, amino acids and microelements (Fra’s et al. 2016; Jonnala et al. 2010). In the dairy industry, the triticale plant has many different functional properties that can be used.

Triticale has a higher content of dietary fiber (about 15%), including wheat and oats, among other grains that are moderate to the parental ratios of wheat and rye but have higher commercial importance compared to cereals (Rakha, 2011; Rakha et al.2011).

Figure 2. A Viev From Triticale Field in Konya-Turkey (Photes taken by Dr. Emel ÖZER)

HUMAN USES

Triticale is reported to be suitable for human consumption due to the valuable nutrient composition its contains; by-products such as bran and straw are reported to be promising as a source of valuable phenolics and dietary fibers for future functional foods. (Hosseinian & Mazza, 2009). Triticale predicted as a suitable grain for the human diet but not like wheat and oats when its compared: its application in the food industry is still very limited (Pena, 2004).

Triticale when used alone appeared to be unsuitable for bread but not for cookie production. Triticale and wheat mixed flour is used for bread making (McGoverin et al. 2011).

Last two decade: more attention has been paid to improve functional food and food ingredients with increased health benefits and acceptable sensory properties from triticale. Studies on such as some chemical constituents (e.g. starch and non-starch polysaccharides) of triticale as well as the genetic variability in nutritional composition getting more attraction. From Triticale different food and beverage products have been developed, including bakery products (e.g. bread and cookie), pasta, malt, spirit, yoghurt, and biodegradable and edible films.

The fact that world production of triticale and other grains is not proportional to the increase in the number of people is known to everyone. New triticale varieties developed by breeding techniques, protein content, especially lysine value increased, biological properties and grain quality were significantly improved. These species allow for wider use in human nutrition, for example, to bake bread by mixing it with wheat flour. (Baier and Gustafson, 1996; Aguirre et al., 2002).

The use of triticale in bakery products production is limited due to its high alpha amylase activity and poor rheological properties of the dough and its low gluten content (Fra's et al., 2016). For malting and brewing Triticale has potential due to high α-amylase and proteolytic activities as well as low gelatinization temperatures of starch (Munoz-Insa et al. 2016).

Different genotypes of Triticale varieties varying in chemical composition was used for bread baking (Frás et al., 2016; Navarro-Contreras et al., 2014). Good quality for baking good bread depended on the triticale genotypes.

Triticale-the specific bread volume obtained by mixing with wheat flour was higher than the full triticale. This can be attributed to the higher content of total polymeric protein (soluble gluten and no longer extractable protein) and the lower albumin content of plain triticale flour (Navarro-Contreras et al. 2014).

From triticale flour such as cookie, pasta, and tortilla were also produced (Martinez et al. 2012; Pattison & Trethowan, 2013). Vaca-García et al. (2011) reported from their studies that by adding of 10% of triticale flour resulted in acceptable tortillas.

By selecting triticale genotypes suitable for the purpose and using optimal processing / formulation, quality products can be produced. Some functional components, such as hydrocolloids, are used to improve the quality of food products. Yeast technology, widely used in wheat and rye product formulations, can also be used to improve the application range of triticale flour production (Zhu, 2018). Triticale bran has been used for prebiotic and antioxidant benefits as an ingredient in yogurt making (Agil and Hosseinian, 2012). Triticale can be fractionated to obtain various components such as starch, dietary fiber and proteins, which can be used for food and non-food uses further studies (Zhu, 2018).

Of our consumers is the most modern and health conscious, choosing the varieties available for human consumption or nutrient-rich as the degree of selection of genotypes for the upbringing of the line, triticale can increase interest in new materials as valuable nutritious grain of the use of the preferences is increasing. (McGoverin et al. 2011; Lango et al., 2017).

Figure 3. Triticale Spikes Before Harvest (Photes taken by Dr. Emel ÖZER)

BIOETHANOL

For bioethanol production different source of plant materials are used around the world. In USA: maize; Germany and Poland; wheat and rye; and Sweden; wheat and triticale. (Davis-Knight and Weightman 2008)

Triticale is a feedstock with high potential for bioethanol production, giving alcohol yields per tonne of grain comparable with a good distilling wheat at equivalent grain protein content. In all scenarios studied; the net benefits in terms of reducing Greenhouses Gas emissions associated with bioethanol production were greater for triticale than for wheat, principally due the lower N requirement of triticale (Davis-Knight and Weightman 2008).

Triticale is a hopeful raw material with high potential, especially for bioethanol production, and has equivalent grain protein content to provide alcohol yield per tonne of grain compared to a fine distillate wheat. For net benefits in terms of greenhouse reduction the gas emissions associated with bioethanol production are greater than for triticale mainly due to the lower N requirement.

Beyond its agricultural benefits and lower grain protein content, triticale is considered to have beneficial grain quality benefits for bioethonol production i.e. higher auto-amylolytic activity than other grains (including wheat and rye). For this reason, it has been reported in studies that it is used without adding enzymes to triticale, thus reducing the consumption of enzyme preparations up to 50% (Kučerová, 2007).

PROBLEMS OF TRITICALE

Global warming, which has begun to make itself felt seriously all over the world, and the resulting climate changes have started to significantly affect vegetative production in many countries. Especially frequent droughts, extreme and unexpected rainfall disrupt the usual systems and balances in the agriculture of many countries. Changes in ecology make it necessary to make changes in the existing product pattern and to develop products that can adapt to new conditions.

It is necessary to increase the planting area of forage plants, which is around 3% in our country. Because there is a serious shortage of roughage in our country. While making the most efficient use of intensive agricultural lands, necessary studies should be carried out in order to make food and feed production in marginal areas.

Many factors such as seed bed preparation, sowing time, sowing method, sowing depth, sowing frequency, seed and fertilization, which are among the breeding techniques and which are generally made with application errors, are effective in the increase of yield. Such applications must be applied correctly.

Milling yield is a problem associated with triticale for food applications (Dennett & Trethowan, 2013). Effects of grain hardness and size, and tempering moisture on milling yields of triticale were studied. Increasing tempering moisture decreased the milling yield and ash content of flour, regardless of the triticale genotypes. Milling yields of triticale were lower than those of wheat by 7.1–10.1% with the tempering moisture between 11 and 15%. Mostly some triticale varieties have solid grain so had a very low milling yield. Regardless of tempering moisture, the ash content of triticale flour was higher than that of wheat. Lower tempering moisture content progressed the milling yields and flour protein content of triticale. The high ash content of triticale flour may be more suitable for certain types of products such as cookies of which the colour is not an important (Dennett & Trethowan, 2013). Triticale grain produces less particles in milling than soft and hard wheat, resulting in lower energy consumption for milling (Naik et al. 2010).

Frequent droughts, extreme and unexpected rainfall have deteriorated the agricultural systems and balances of many countries to significantly affect their crop production. In addition to these changes in ecology, the increasing world population has caused the resources to decrease rapidly. This has led to a necessity to incur a steady increase especially in the production of cereals as well as the necessity to produce in marginal areas, which has led researchers to identify new product groups and increase unit yields. Triticale is one of the first successful study on this issue (Kün 1996).

Triticale awns is very thick so sometimes a problem to be consumed by the animals in the silage. Setting the silage time very well eliminates this problem.

In Turkey there are problems in Triticale seed production, and farmers have problems finding certified seeds. Since triticale is produced in dry conditions, seed companies do not want to produce certified seeds in triticale, due to the high cost and low efficiency of producing certificated seeds.

Global climate changes cause low yields in many plant species and grains. For this reason, the cultivation areas of triticale, one of the plant species that are least affected by adverse climatic and environmental conditions, should be increased rapidly.

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CHAPTER 14

OATS (Avena *sativa* L.) CULTIVATION

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INTRODUCTION

Oats are a new cultivated plant compared to wheat and barley. Oats are used in human nutrition and animal feed in the world, however, mostly are used as livestock feed (Wang et al., 2007). Oats have more organic substances and mineral elements than wheat and barley straw due to its softer stems and leafly stracture. Oat (*Avena sativa* L.) is used as animal feed as grain and hay. Animal feed is in the form grain, green forage, silage and straw, is also used as a support plant in the mixtures of legumes such as vetch and fodder peas. A very good feed for all animals, is fed as crushed and oatmeal for animals.

Oats are one of the most produced cereal crops in Europe after wheat, barley and corn. About 10 % of the production is used in human nutrition. It is also used in the production of breakfast foods such as pasta, bread, biscuits, cakes and snacks. Oats grain contains high levels of carbohydrates, oil, protein, soluble dietary fiber, β-glucan, mineral elements and vitamins (Flander et al., 2007). Among the cereals, oats are used in pet feeding, due to their high protein content and high quality, as well as having the highest oil content. The crude oil contents of some cereals are 5.0-9.0% in oat, 2.1-3.8% in wheat, 0.1-3.1% in rice, 4.0-5.5% in millet, 3.9-5.8% in maize, 3.3-4.6% in barley, 2.0-3.5% in rye and sorghum. 2.1-5.3%, respectivly (Morrison, 1978).

While the protein content in husked oats is 10-18%, it changes between 12 % and 24% in naked oats. Oats contain higher amounts of oil (3-12%) and unsaturated fatty acids than wheat and barley grains (Saastamoinen et al., 1992). The high amount of unsaturated fatty acid content of oats, increases its nutritional quality (Aro et al., 2007).The substance of Avenin ensures the development of young organisms and the strengthening of the muscles in horses (Kun, 1988).

Oat flour and oatmeal are consumed for breakfast in human nutrition. Oat flour and soup are used for feeding of young bodies and in the treatment of some skin diseases. Oats are a good alternative food for celiac patients who have to be fed gluten-free food, especially because it does not contain gluten. Oats have a different protein sequence than wheat, barley and rye. For this reason, oats are preferred in the diets of most celiac patients (Pulido et al., 2009).

Oats contain a significant amount of dietary fiber and water-soluble beta-glucan (β-glucan). The oats have insoluble dietary fiber between 4.1-9.6% (6.9%) and soluble dietary fiber between 4.4-8.4% (6.9%), they are equal to each other and the total amount of fiber is between 10.9-16.3 % (13.8%). Among the cereals, oats have the highest amount of total β-glucan with a ratio of 5.5-11% (Flander et al., 2007; Maki et al., 2007). Due to the nutritional properties of oats, its flour and bran are added to bakery products (Figure 1). It is appropriate to add oat flour to bread, biscuits, cake and breakfast products at a rate of 10-40% (Figure 2). The oat flour contains no or a small amount of gluten 2.3-17.5 (7.0) mg kg^{-1} (Dvoracek et al., 2020), that is why it is not possible to make bread using 100% oat flour (Londono et al., 2014).

Figure 1. Husked oats, groat/hulled oats and oats flour

In order to produce an acceptable quality bread, oat flour should be mixed with wheat flour (Kelesoglu, 2011). In Turkish Food Codex Bread and Bread Types regulation, oat bread is defined as a type of bread produced in accordance with its technique by adding oat flour, oat crumb, oat breakage and oatmeal or a mixture of these to wheat flour at a rate of at least 15%.

Figure 2. Oat bread and biscuit

Oat breeders generally aim to develop high-yielding varieties, with a short growing period, resistant to cold, disease and lodging and grain shedding. In addition to these traits, the quality is also very important in oats as in all other crops. Quality criteria vary according to the purpose. If the objectives of breeding is animal feeding; high protein, oil, starch and beta glucan ratio, low husk ratio, are important. On the other hand, if human food is aimed; Oat varieties with high protein, dietary fiber and beta glucan ratio and low oil and husk ratio should be developed. In both cases, the thousand grains weight and test weight should be high (Peterson et al., 2005).

ORIGIN AND TAXONOMY OF OATS

It is not known exactly when the oat cultivation started. Melzew and Vavilov reported that the oats were cultivated in Anatolia during the years of Jesus' life, and then it spreaded from here to the west and north. Archaeological discoveries had shown that the origin of oats was in the Middle East, especially around the Mediterranean. Oats were domesticated thousands of centuries after wheat and barley. It is thought that oats spreaded as a weed from the Near East to Central and Northern Europe 4,000-5,000 years ago (Gokcora, 1969, Gokgol, 1969; Yurur, 1994; Lippi et al. 2015). Cultural oats *Avena sativa* were developed by selection from wild oat *Avena fatua*, on the other hand, some researchers say that they were selected from *Avene fatua* through mutation, while some researchers reported that *Avena sativa* and *Avena fatua* were developed from wild oat *Avena sterilis* (Gokcora, 1969, Gokgol, 1969; Yurur, 1994).

Oats are annual grasses belonging to the genus *Avena* in the family Poaceae and they are grown primarily for use as livestock feed. Several species of oats are grown commercially in different regions of the world, including Avena *sativa* (common oat), *Avena byzantina* (Algerian or red oat), *Avena nuda* (naked oat). There are also two wild oats species such as *Avena fatua* and *Avena sterilis*. Oats are classified in 3 groups according to their chromosome numbers and genome structure. Oat species (*Avena spp.*) have three ploidy levels, diploid 2n = 14, tetraploid 2n = 28 and hexaploid 2n = 42, according to chromosome number and genome structure. Wild oats, A. Fatua and A. Sterilis and husked cultural oats *A. Sativa*, and *A. Byzantina* and naked oat *A. Nuda* have 2n = 42 chromosomes. The genome of hexaploid oats is AABBCC (Gokcora, 1969, Gokgol, 1969; Yurur, 1994; Loskutov and Rines, 2011; Lin, 2012).

OATS CULTIVATION AREA, PRODUCTION AND YIELD IN THE WORLD AND TURKEY

Oats cultivation and production in the world is the highest between 1935-1939, with an average of 58.2 million ha of cultivation area and an average production of 62.8 million tons (Gokcora, 1969)**.** The cultivation and production of oats have decreased in the world after this date. Between 2010 and 2019, the cultivation area was fixed between 9.0-10.0 million ha and production was fixed between 22.0-25.0 million tons (Table 1). Oat yields increased from 1935-1939 until 2017 (Anonymous, 2021b). Oats has an important place among ceraels in the world, with 9.42 million hectares of cultivation area and 23.1 million tons of production (Anonymous, 2021b). Important oat growing areas in the world are between 40 ° and 60 ° latitudes in America, Europe and Asia continents and some oat production is also carried out in South America, Australia and New Zealand in the southern hemisphere (Morrison, 1978).

Table 1. Oats Planting Area, Production and Yield in the World between 1935 and 2019

Year	Area sown (ha)	Production (ton)	Yield (ton ha^{-1})
1935-39	58.154.000	62.841.000	1.08
1940-44	56.900.000	61.992.000	1.09
1945-49	52.380.000	57.136.000	1.09
1950-54	53.375.000	60.480.000	1.13
1955-59	47.309.000	59.216.000	1.25
1960-64	33.450.000	49.600.000	1.49
1965	29.386.814	45.356.066	1.54
1970	30.677.761	52.411.105	1.71
1975	29.269.587	45.418.289	1.55
1980	24.697.330	41.433.288	1.68
1985	24.781.851	47.425.037	1.91
1990	20.679.705	39.917.119	1.93
1995	16.541.668	28.926.844	1.75
2000	12.661.871	26.046.484	2.06
2005	11.351.906	23.566.012	2.08
2010	8.981.037	19.233.197	2.14
2015	9.692.303	22.558.456	2.33
2016	9.390.851	23.279.383	2.48
2017	9.906.888	25.337.537	2.56
2018	9.692.985	22.588.269	2.33
2019	9.418.493	23.104.147	2.45

The countries with the high grain oat cultivation area in the world in the year 2018-2019 are Russia (2.426.333 ha), Canada (1.171.100 ha), Australia (938.129 ha), Poland (495.500), Brazil (453.430 ha), Spain (453.430 ha), USA (334.270 ha), Finland (297.500 ha), Argentina (238.166 ha), Kazakhstan (243.480 ha), and Ukraine (181.900 ha), respectively (Table 2).

Table 2. Planting Area, Production and Yield of the Main Oats Cultivating Countries in 2018-2019

Country	Sown Area (ha)	Production (ton)	Yield (ton ha^{-1})
Russia	2.426.333	4.424.433	1.82
Canada	1.171.100	4.237.300	3.62
Australia	938.129	1.134.619	1.21
Poland	495.500	1.209.580	2.44
Brazil	448.072	920.439	2.05
Spain	453.430	841.200	1.86
USA	334.270	771.440	2.31
Finland	297.500	1.187.480	3.99
Argentina	238.166	571.630	2.40
Kazakhistan	243.480	267.006	1.10
Ukraine	181.900	422.000	2.32
World	9.418.493	23.104.147	2.45

The highest grain oat yields in the world were obtained in 2018-2019; in Ireland (8.10 t ha^{-1}) in UK (5.91 t ha^{-1}), in Netherlands (5.81 t ha^{-1}), in Switzerland (5.61 t ha^{-1}), in New Zealand (5.51 t ha^{-1}) in Belgium (5.23 t ha^{-1}), in Luxembourg (5.16 t ha^{-1}) (Anonymous, 2021). The lowest grain yields were obtained in Morocco (0.65 t ha^{-1}) in Ecuador (0.74 t ha^{-1}) and North Africa (0.79 t ha^{-1}) (Table 3).

Table 3. The Countries with the Highest and Lowest Oat Grain Yield in the world in 2018-2019.

Country	Yield (ton ha^{-1})	Country	Yield (ton ha^{-1})
Ireland	8.10	Luxembourg	5.16
England	5.91	Turkey	2.45
Netherlands	5.85	North africa	0.79
Switzerland	5.63	Ecuador	0.74
New Zeland	5.51	Morocco	0.65
Belgium	5.23	World	2.45

Oats production in Turkey is not at the desired level as in the world. Turkey meets 1.16% (109.5 thousand ha) of world oat cultivation area and 1.15% (265 thousand tons) of production (Anonymous, 2020). Oats sown areas in Turkey increased from 1930 until the years 1960-1965. After this date, oat cultivation area decreased until 2011 and after then increased slightly and has not changed in the last four years. While oat yield increased from 1930 to 2010, it remained stable between 2.3-2.5 t ha^{-1} after this date (Gokcora, 1969; Anonymous, 2021a).

Table 4. Grain Oat Planting Area, Production and grain yield in Turkey between 1930-2020

Year	Area sown (ha)	Production (ton)	Yield (ton ha^{-1})
1930	166.400	163.119	0.98
1935	229.119	231.988	1.01
1940	394.055	327.596	0.83
1945	260.660	121.546	0.47
1950	302.376	315.601	1.04
1955	369.000	356.000	0.96
1960	430.000	530.000	1.23
1965	400.000	540.000	1.35
1971-75	283.000	400.000	1.41
1976-80	223.000	373.000	1.67
1981-85	173.000	321.000	1.86
1986	158.000	300.000	1.90
1990	137.000	270.000	1.97
1995	148.000	250.000	1.69
2000	153.600	314.000	2.04
2005	133.000	270.000	2.03
2010	88.300	203.870	2.31
2011	85.863	218.040	2.54
2012	89.327	210.000	2.35
2013	92.549	235.000	2.54
2014	93.862	210.000	2.24
2015	103.457	250.000	2.42
2016	99.438	225.000	2.26
2017	112.880	250.000	2.21
2018	105.825	260.000	2.46
2019	109.823	265.000	2.41
2020	113.263	314.528	2.78

Oats planting area was 113.3 thousand hectares and oat production was 314.5 thousand tons in Turkey in 2020 (Table 4). Oats growing area for green forage production slightly increased between 2012 and 2016 in Turkey. Oat cultivation area for green forage production in Tukey increased 22.6 % in 2017, 100.9% in 2018, 19.9% in 2019 and 26.6% in 2020 (Anonymous, 2021a). Oat green forage productions also increased in parallel with the planting area.

Oat green forage yields increased from 2012 to 2016, however, it decreased after this date. Oat green forage production was 385 thousand tons and its growing area was 324 thousand hectares in Turkey in 2020 (Table 5).

Table 5. Green Forage Oat Planting Area, Production and Yield in Turkey, in the last years

Year	Area sown (ha)	Production (ton)	Yield (ton ha^{-1})
2012	80.528	93.416	11.6
2013	79.941	108.817	13.6
2014	82.503	115.655	14.0
2015	82.474	118.029	14.3
2016	86.725	154.985	17.9
2017	106.309	175.532	16.5
2018	213.571	284.369	13.3
2019	256.008	315.580	12.3
2020	323.987	385.048	11.9

Oats are cultivated spring crop in Eastern Anatolia, it is grown as spring crop in some parts and winter crop in some parts of Central Anatolia and winter crop in the Mediterranean, Marmara and Aegean Regions. Oats are grown as grains in Central Anatolia and the Marmara regions in Turkey, the most important green forage oat production region is Marmara, as it is done in some provinces of the Aegean and Eastern Anatolia regions. The most grain oat production areas were carried out in Ankara (16.783 ha), Sivas (13.841 ha), Konya (89.076 ha) and Eskisehir (64.471 ha) in Turkey in 2019-2020 production year (Anonymous, 2021a). On the other hand, the important green forage oat produced provinces were Kars (72.537 ha), Balıkesir (26.256 ha), Çanakkale (20.712 ha) and Sivas (20.138 ha), respectivly (Table 6).

Table 6. The Main Grain Oats and Green Forage Oats Produced Provinces in Turkey in 2019-2020.

Grain Oats Sown Area		Green Forage Oats Sown	
Provinces	Sown area (ha)	Provinces	Sown area (ha)
Ankara	167.837	Kars	725.373
Sivas	138.412	Balıkesir	262.565
Konya	89.076	Çanakkale	207.127
Eskişehir	64.471	Sivas	201.385
Karaman	63.708	Kastamonu	172.965
Nevşehir	53.044	Erzurum	135.593
Kocaeli	47.398	Bayburt	129.305
Ç.kale	46.250	Kütahya	122.362
Niğde	42.500	Ardahan	121.753
Ardahan	141.474	Burdur	39.616
Türkiye	1.098.227	Türkiye	1.132.933

OATS CULTIVATION

Oats have the highest climate request among the winter cereals. The regions with an annual rainfall of 700-800 mm are the most suitable for oat cultivation. In sandy soils, water shortage in arid and hot regions affects negatively the oat crop, especially during generative period. Oat variety that is not resistant to drought, also it is not resistant to winter hardiness. Among the winter cereals, the soil selectivity is the least winter cereals crop after rye. Oats can be grow even in the most unproductive soils with sufficient moisture. In order to obtain high yield in oats, it is needed a cool, humid, and rainy climate conditions from germination to heading stage (Kun, 1988; Peltonen-Sainio and Rajala 2007). Oats are an alternative crop that can grow on all kinds of unproductive and sandy soils where wheat and barley cannot be grown. Oats are grown for green forage and silage in the Mediterranean, Marmara and Aegean Regions. After the early spring oat harvest, a second crop can be grown in these regions such as maiz, soybean and cotton etc.

Among cereals the oats have a very deep root system. In general, there is a relationship between root depth and winter hardiness in the cereals. The deep roots of oats are due to the need for excess water. The leaf sheath of oats is hairless and it is hairy in some varieties. The leaf blade is curved from right to left in oats and from left to right in barley, wheat and rye, on its own axis. when Starting stem elongation, the typical genus-specific curl directions disappear, the curl can be seen in the same or opposite direction (Coffman, 1977; Yurur, 1994). Oats has a small auricle organ that grasps the stem like a pair of pincers where the leaf blade is attached to the stem. The auricle is best developed in barley and grasps the stem as pincers, followed by wheat and rye, respectively, and grasps the stem almost completely (Figure 3). In oats, the auricle is not developed at all (Yurur, 1994).

Ligule is a membrane-like organ located in the form of an extension of the leaf sheath between the stem and the leaf blade at the point where the leaf blade is attached to the stem. Ligule is best developed in oats among small grains (Figure 4).

Figure 3. Oats auricle on the left, wheat auricle in middle, barley auricle on the right

It is followed by barley, and less developed in wheat and rye (Yurur, 1994). The varieties with dark green leaf color are more resistant to winter hardiness than light green colored varieties. Generally, the winter and drought resistant varieties have small and narrow the leaf blade.

Figure 4. Oats ligule

The number of stomata per unit leaf area increases, in small leaves. This means that the cell water of the transpiration plant becomes more concentrated. Oats have thicker and wider leaf than the other cereals (Coffman 1977; Yurur, 1994). The flower of winter cereals such as wheat, barley, rye and triticale are in the form of spike, however oats has a flower in the form of panicle (Figure 5). The number of spikelets in the oat panicle can be 60-70 under suitable conditions. The spikelets are attached to the panicle branches with a pedicel, these branches emerge from the nodes located on the panicle axis. The number of node is 5-7 and the nodes form at the tillering stage. The flower structure of all winter cereals except rye, are monoclinus and self-pollinated (Coffman, 1977; Yurur, 1994).

Figure 5. Oats panicles

The spikelet of barley has one flower, whereas, the number of flowers in a spikelet of wheat, rye and oats has more than three or it can be at most 11. Naked oat can have more flowers. The number of flowers produced grain in a spikelet is 1 in barley, 2-4 in wheat, it is maximum 6 in wheat, 2 in rye, 2-3 in oats at most 4 (Figure 6). Oats have one female and three male organs. Flowering and pollination in oats occurs towars from top to bottom (basipetal) in the panicle, and it occurs towars from bottom to top (acropetal) in the spikelet. The uppermost grain of the spike is the smallest and the lowest one is the biggest (Yurur, 1994).

Figure 6. Oats spikelet and it has 2- 3 florets/grains

The number kernel per panicle and grain weight varies according to the number of spikelets per panicle and the number of grains per spikelet.

As the number of grains per panicle increases, the grain gets smaller. The number of grains per panicle varies between 40-200 depending on the variety, climatic conditions and planting density (Figure 7).

Figure 7. Oats panicles on heading stage and riped/matured panicle on the right

Oats grain is husked like barley, but the florets are not homogeneous. The hull rate in oats varies between 12.1-31.1 % depending on the variety and growing conditions (Kahraman et al., 2019). The test weight of genotypes have higher hull rate is lower. Oats has the lowest thousand grain weight and test weight among the cereals. Thousand grains weight of oats varies between 21.1-44.0 g, the test weight is between 42.9-58.9 kg and the beta glucan is between 2.9-5.0 % (Kahraman et al., 2019). Oats are named as white, red-brown, black and yellow according to their grain husk colors (Figure 8).

Figure 8. Different colored oats grains

Oats is grown as summer and winter crops in Turkey. The winter oats are planted is done in October, November and December, and the summer oats are planted in February, March and April. In planting oats, 500 seeds per square meter, and between 150 and 200 kg of seeds per hectare are used. When oat is planted for green forage and silage, the amount of seed is used 20% more than the grain oat production. Therefore, it can be obtained high plant height and larger green parts.

In oat fertilization, in productive and rainy regions, 150-180 kg of pure nitrogen is applied per hectare. Before sowing, 20.20.0 compound fertilizer containing nitrogen and phosphorus is used, urea (46%) is applied at the tillering stage and ammonium nitrate (26%) is applied at the stem elongation stage. The oat harvest is done between the end of June and July moths, although it varies according to the planting time and regions. Oats are more susceptible to lodging as they have a longer and softer plant height than the other cereals. Since the risk of grain shedding increases with the delay of the harvest, the oat harvest should be done on time in order to prevent loss of yield due to grain shedding

Oat Breeding and Registered Varieties in Turkey

The first oat breeding study was started in Adana, Eskisehir and Adapazari seed Improvement Station in Turkey. These seed stations were established in 1925 and the first breeding work on oats was started in 1926 at the Eskişehir seed breeding station. İstanbul Yesilkoy Seed Breeding Station was established in 1926 and it started to test local and foreign varieties in its second year (1927), by introducing and selecting varieties of oats. As a result of breeding studies in our country, first Apak and Bozkır oat varieties were developed by Eskişehir Seed Breeding Station and registered in 1963. Today, the oats breeding are carried out at Bahri Dagdas International Agricultural Research Institute, Trakya Agricultural Research Institute, Transitional Zone Agricultural Research Institute and Agean Agricultural Research Institute in Turkey (Gokgol, 1969). The first oat hybridization was initiated by Trakya Agricultural Research Institute in Turkey in 2011.

The objectives of oat breeding are to develop alternative-winter type varieties suitable for human and animal feed, which have wide adaptability, high yielding, resistant to hardiness, drought, lodging and the diseases and the pests in the region. In the development of green forage or silage varieties, the tall varieties with wide and abundant leaves, resistant to lodging and cold tolerant is desired. The crossing, selection and introduction methods are used in oat breeding study.

A total of 35 oat varieties have been developed and registered in Turkey until 2020. The twenty four of these varieties were recorded and the eleven of them were not recorded in the national varieties list. All of the eleven oat varieties were Bozkır, Apak, 4286, 4047, 9885, Arlington, Yesilkoy 1779, Yesilkoy 330, Ankara 76, Ankara 84 and Checota. These varieties were developed by public institutions (Anonymous, 2020). The sixteen of 24 varieties were registered by public institutes and eight of them were registered by private companies (Table 7). Two of these varieties, Otag and Alhama, were registered for animal feeding and the others for grain production (Anonymous, 2020).

Table 7. The Registered National Oat Varieties in Turkey

	Variety Name	Registration date	Maintainer
1	Faikbey	01.4.2004	Bahri Dagdas International Agr. Research Ins./Konya
2	Seydisehir	01.4.2004	Bahri Dagdas International Agricultural Research Institute / Konya
3	Sebat	08.4.2011	Trakya Tarım ve Vet Tic. Ltd. Şti. / Tekirdag
4	Yeniceri	12.4.2013	Bahri Dagdas International Agricultural Research Institute / Konya
5	Kahraman	11.4.2014	Trakya Agricultural Research Institute / Edirne
6	Kirklar	11.4.2014	Trakya Agricultural Research Institute / Edirne
7	Sarı	11.4.2014	Aegean Agricultural Research Institute / İzmir
8	Fetih	11.4.2014	Aegean Agricultural Research Institute / İzmir
9	Haskara	26.3.2015	Aegean Agricultural Research Institute / İzmir
10	Albatros	26.3.2015	Ata Toh. Isl. San ve Tic. A. Ş.
11	Bc Marta	13.4.2017	BC Institüt Tar. Prod. Oto San ve Tic. Ltd. Şti.
12	Dirilis	13.4.2017	Bahri Dagdas International Agricultural Research Institute / Konya
13	Arslanbey	13.4.2017	Sutcu Imam Uni. Faculty of Agr./Kahramanmaras
14	Kuçukyayla	13.4.2018	Trakya Agricultural Research Institute / Edirne
15	Kehlibar	13.4.2018	Som Un San. ve Tic. Ltd. Şti. Luleburgaz / Kirklareli
16	Kayı	09.4.2019	Aegean Agricultural Research Institute / İzmir
17	Kupa	09.4.2019	BC Institüt Tar. Prod. Oto San ve Tic. Ltd. Şti.
18	Halkalı	05.5.2020	Trakya Agricultural Research Institute / Edirne
19	Kazan	05.5.2020	Bahri Dagdas International Agricultural Research Institute / Konya
20	Katmerli	05.5.2020	Bahri Dagdas International Agricultural Research Institute / Konya
21	Mayas	05.5.2020	Aegean Agricultural Research Institute / İzmir
22	Somun Yildizi	05.5.2020	Som Un San. ve Tic. Ltd. Şti. Luleburgaz / Kirklareli
23	Otag	06.5.2020	Bahri Dagdas International Agricultural Research Institute / Konya
24	Alhama	06.5.2020	Semillas Fito Tarım San. Tic. A.S.

These varieties were developed by public institutions (Anonymous, 2020). The sixteen of 24 varieties were registered by public institutes and eight of them were registered by private companies. Two of these varieties, Otag and Alhama, were registered for animal feeding and the others for grain production (Anonymous, 2020).

DISEASES AND PESTS OF OATS OATS DISEASES

1-Rust Diseases

1a-Oat Crown rust (*Puccinia coronata* f. sp. *avenae*)

Oat-crowned rust is the most common and significant loss-making disease of oats. When this disease is seen rather early than stem rust in early spring, Oat-crowned rust causes significant yield and grain quality losses in climatic conditions (Figure 9). The disease occurs in the spring with light orange-yellow pustules on the leaves (Zillinsky, 1983; Anonymous, 2008; Omidvar et al., 2018; Sunulu et al., 2020).

Figure 9. Symptoms of crown rust on oat leaves

1b- Oat stem rust (*Puccinia graminis* Prers. *f.sp. avenae*)

Disease symptoms most commonly appear on the stems and leaf sheaths, but leaf blades and panicles may also become infected (Figure 10). Urediospores develop in pustules (uredia) that rupture the epidermis and expose masses of reddish-brown spores. The pustules are larger than those of crown rust, oval or elongated, with loose or torn epidermal tissue along their margins. They may appear on both surfaces of the leaf. They continue to be produced until the plants approach maturity. Stem rust appears in the late period of growing, therefore, it is not economically very important (Zillinsky, 1983; Anonymous, 2008).

Figure10. Symptoms of stem rust on oats leaves and stems

2-Septoria Leaf Blotch (*Septoria avenae f.sp. avenae*).

The optimum germination temperature of S. tritici conidiospores is 20-25 ºC. The spores that come to oat leaves by wind and rain infect the leaf when wetness remains on the leaf for 6 hours. As a result of the development of the disease, pycnids are formed on the leaves. The spots on the leaf are small, irregular, dark reddish-brown oval spots (Figure 11). As a result of the expansion and unification of these spots the entire leaf is covered with spots. Pycnites form small dark spots on the spots (Zillinsky, 1983; Yurur, 1994).

Figure 11. Symptoms of Septoria leaf blotch on oats leaves and leaf blotch on the right

3-Oats Leaf Spot (*Helminthosporium Avenae*) (Bri. And Cav.)

Leaf blotch, caused by *H. avenae*, is common disease of oats. This disease causes damages both at the seedlings and at late growing periods. In the first periods of the disease, these typical reddish spots provide great convenience for the diagnosis of the disease. As the disease progresses, the spots spread over the leaf surface (Figure 11). Infected leaves turn yellow and dry depending on the severity of the disease (Zillinsky, 1983; Yurur, 1994).

4- Oats Smut (*Ustilago spp*.)

The plants affected by the disease can not be distinguished from the plants unaffected until they reach the flowering period. When the enfacted plants reach to the panicle exurtion period, the diseased panicles are distinguished from the undiseased ones by their blackened appearance. The matured smut spores in oat panicles are dispersed by wind, rain and insects and land on the other panicles (Zillinsky, 1983; Martens et al., 1985; Yurur, 1994; Anonymous, 2008).

4a-Oat Loose Smut *(Ustilago nigra, U. Avenae)*

The spores of the both loose and semi loose smut are dispersed around when membranes surrounding the panicles teared (Figure 12). Early emergence of heads; dark green or black masses in place of kernels.

4b-Oat Covered Smut (*Ustilago hordei, U. Kolleri*)

The membrane surrounding the panicle does not break in covered smut.

Figure 12. Oats panicles with black loose smut on the left and covered smut on the right

5-Bunt (*Tilletia foetida* spieces)

The infected oat panicles cannot be distinguished from healthy ones until they reach the milk stage. The colors of the diseased panicles are bluish-green and they stand upright because they are lighter than the healthy ones. Diseased panicle grains emit a smell similar to rotten fish. If there is a grain infected with the disease, the spores of the pothogen in black-brown emerge from this blunt grain (Zillinsky 1983; Anonymous 2008).

6-Powdery Mildev (*Erysiphe graminis f. sp. avenae*)

Powdery mildew occurs in high humid and hot regions in early spring. It appears as white mold spots on the lower leaves of the plant (Figure 13). The optimum germination temperature of conidospores is 10 ºC (0-35 ºC). First, white-gray mold spots (pustules) are seen on the upper surface of the lower leaves and then they brown over time. First, local yellowing, then necrosis are seen on the diseased leaves, and then the leaves become dry (Zillinsky 1983).

Figure 13. Symptoms of powder mildew on oats leaves

7-Downy Mildew (*Sclerophthora macrospora*).

Downy Mildew is often seen in flooded or irrigated areas. The disease symptoms are most commonly seen as yellowing in the leaves of host plants, severe stunting and excessive tillering (Figure 14). The stems of the diseased plants become thicker and the leaves bend, their panicles usually do not excure (Zillinsky, 1983; Anonymous, 2018).

Figure 14. Symptoms of downy mildew on oats

8-Oats leaf blight (*Alternia longipes*)

Yellow halos and brown oval spots appear on oat leaves. These small brown spots initially are seen at the lower leaves and then to the upper leaves. Later, these spots unite and they are seen as burn covering the leaf surface, including the leaf blade. They turn into dark brown oval or necrotic spots with an irregular light yellowish border (Zillinsky, 1983)

9-Barley Yellow Dwarf Virus

Although the virus infects most cereals, it does the most serious damage to oats, barley and wheat. Macrosiphum (Sitobion) avenae is the most important vector aphid of BYDV. If the infection occurs early growth stage, the yield losses is high. The vectors carry the virus in its bodies and allow it to spread throughout its life. Reddish purple discoloration of the leaves, sometimes yellowing and hardening of the whole plant, are the most common symptoms (Figure 15). The yellow streaks occurs along the leaf in the young leaves (Zillinsky, 1983; Watkins and Lane, 2004; Anonymous, 2008).

Figure 15. Symptoms of Barley Yellow Dwarf Virus (BYDV) on oats

10- Oat Bacterial Leaf Blight

Generally, it is a common pathogen in corn, sorghum and soybean, and it has been known as a serious pathogen in also the cereal crops. Early lesions appear as small, light-whitened green, water-soaked spots. When the conditions are suitable, brown-yellow spots grow irregularly. This disease spreads rapidly in a warm and humid environment conditions (Zillinsky, 1983; Martens et al., 1985; Buyukdeveci, 2016).

10a-Bacterial stripe blight (*Pseudomonas syringae* pv. *striafaciens*)

Typical symptoms of the disease; they are bright brown, parallel and elongated lesions on the leaves that can reach a length of several cm. These exudates dry in yellowish color and granular form over time and remain on the leaf and can easily be separated from the leaf surface. It is an important seed-borne bacterial pathogen. The lesions of oat bacterial streak blight are in the form of red or brown streaks and it sometimes spreads across the leaf with a thin yellow border. The spots start from the tip of the leaf and spread to the bottom (Zillinsky, 1983).

10b- Halo Blight oat (*Pseudomonas syringa pv. coronafaciens*)

Halo blight usually occurs in the leaf sheath, sometimes in the leaf blade and the panicles. The Early lesions are small and oval and the water-soaked spots range from straw color to light brown. The yellow (yellow-green) halos form around brown lesions. Brown areas appear around the places where the infection occurred. These bacteria need moist conditions to spread (Zillinsky, 1983; Martens et al., 1985).

OAT PESTS

1-Zabrus (*Coleoptera: Carabidae*) Zabrus spp.

The ground beetle, Zabrus spp., is one of the important and common pest. Zabrus overwinter in the soil in as adult and adult larvae stage. The young larvae pull the fresh leaves of newly germinated crops into their nests in the autumn months when the temperature is normal and at the same time, they cause significant damage by gnawing the root collar in the soil. The adult larvae become harmful by eating leaves and shoots. After larvae damage, the crops are attacked by adults in June (Gokgol, 1969; Anonymous, 2008).

2-Leaf Aphid (*Sitobion avenae*)

The adults and nymphs of the aphids cause damage by sucking the plant sap by forming large colonies on the leaf blade in oats. As a result of sucking, the plant weakens, development stops, and the ripening of the grain is prevented. They secrete enzymes during their feeding, these prevent development by causing abnormal growth and deformities in plants. Generally, the deformity is manifested as the curling of the leaves. They carry and transmit viruses, therefore they cause many the transmission of viral diseases to the plants (Gokgol, 1969; Anonymous, 2008).

3-Cereal leaf beetles (Oulema spp., Coleoptera: Chrysomelidae)

The winter cereal leaf beetle, O. melanopus adults 0.5-0.6 cm long and 0.1 cm wide, head and front wings (elytra) hard. They produce one generation in a year. The adults and larvae of cereal leaf beetle cause damage to grains (Figure 16). The main damage is caused by the larvae. The adults and larvae feed by eating the chlorophyll part on the leaf. As a result of feeding adults and larvae, narrow and long holes are formed on the leaf. When the excessive damage occurs, only a thin membrane remains on the leaf (Anonymous, 2008).

Figure 16. Adult Cereal leaf beetle and larvae on oats leaves

4-Cercopis sanguinolenta (Scopoli, 1763)

Cercopis sanguinolenta have five nymphal stages, and most of their nymphs are surrounded by saliva or foam (Figure 16). When they feed on the stems of *Graminae* family plants, the stems remain short and ears cannot form normally or their grains become thin. It has also been reported to be vectors of some viral diseases. The deformations occur in plants due to toxic substances secreted by nymphs while feeding and thus, the economic damage increases more (Mutlu et al., 2017).

Figure 17. Cercopis sanguinolenta nypmhs and spittle masses on oat leaves caused Cercopis sanguinolenta nypmhs

5.Oats Nematode (*Heterodera major*)

The first symtom of the nematode damage is the leaf tips of plants with nematodes are reddish and stagnation in development. Infestation by nematode results in a stunted, knotted root system. Panicle development is delayed or absent in severe infestations (Araya and Foster, 1992). In the roots of the damaged plants, first white colored and then darkened 0.8 mm in size and gets lemon shape objects are formed from June (Gokgol, 1969; Zillinsky, 1983; Araya and Foster, 1992).

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CHAPTER 15

MAIZE PRODUCTION

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INTRODUCTION

Maize grown in temperate and tropical regions of the world can adapt up to 4,000 m above sea level. Although there is no definite conclusion about the origin and date of maize, as a result of theexcavations carried out in the state of New Mexico of the USA, maize residues that were determined to be 4500-5000 years old were found. In addition, maize flower powders were found in the excavationscarried out in Mexico City, and it was determined that these powders, which were found 60 m deep in the ground, were about 7,000 years old. As a result of archaeological excavations, it is reported that the history of maize is 8 000 - 10 000 years (Jugenheimer, 1958; Berger, 1962; Kun, 1985; Dowswell et al., 1996; Kirtok, 1998, Babaoglu, 2003 and Albayrak, 2019).

The most maize producing country in the world is the United States of America with 355 million tons. This is followed by China with 218 million tons and Brazil with 88 million tons. In China, whichranks first in terms of cultivation area, 36.8 million hectares of production is carried out. The USA ranks 2nd with its production area of 32.8 million hectares, while Brazil comes 3rd with 16.7 million hectares (FAO, 2018).

Maize has a great economic value with its use as an industrial raw material besides human and animal nutrition. It is known that maize, which has become prominent as a biofuel, is used directly or indirectly in around 4000 products.

The way to increase maize production depends on the timely implementation of correct agricultural practices as well as the development of high-yielding varieties and the preference of quality seeds. Even if the most important factor in increasing the unit area efficiency is the selection of the variety, the correct and timely maintenance procedures to be applied during the production period will enable the variety to reach the maximum yield and thus increase our unit area yield.

Soil and Climatic Requirements of Maize

Although maize is not very selective in terms of soil type, it shows high performance in soils rich in organic matter, high water holding capacity and deep structure. Maize damaged by soil airlessness takes nitrogen, phosphorus and potassium from the soil. High yield can be obtained in soils with a pH of 5-8 in terms of soil acidity and with good drainage.

Although maize has varieties that develop between 90-130 days on average, there are also varieties that complete their vegetation in less than 90 days or more than 150 days. The total temperature requirements of these varieties vary between 800-1650 °C. FAO numbers are determined according to these temperature demands and development times. FAO numbers are evaluated between 100 and 800, with 100 indicating very early varieties and 800 indicating very late varieties.

Maize plant requires plenty of water in the soil throughout its growing period. The highest water consumption period is the growing and flowering phases. During the growing period, it is required thatthe summer rainfall should not fall below 200 mm or even be above 400 mm. During the growing period, 700-750 mm of water will provide optimum yield. This need should be met by irrigation in production areas where this amount cannot be met by rainfall. Maize plant with high water needs consumes an average of 270 g of water in order to produce 1 g of dry matter (Kirtok, 1998). Contrary to the view that excessive irrigation increases yield, Kanber et al. (1990) reported that excessive irrigation does not increase yield and that such excessive irrigation is often unnecessary.

The soil temperature is required to be at least 8-10 ° C in order for the sown maize seed to germinate. While the soil depth temperature of 5-10 cm should exceed 15 ° C for a rapid germination, the most suitable germination temperature is 25 ° C.

Although maize is a hot climate plant, it does not like extreme temperatures and the suitable growth temperature is between 20-30°C. Increasing temperature and exceeding 35 ° C will cause maize to lose more water by transpiration than its received with roots. In such cases of temperature rise, the days to tassel is shortened. At temperatures above 32 ° C during the pollination period, it causes fertilization abnormalities and decreases in grain filling in the ear.

Soil Tillage

The purpose of tillage is to prepare a suitable environment forthe seed to be sown, to bury the stubble residues in the soil, to aerate the soil, to eliminate weeds and to accumulate water in the soil. It wants the soil where maize will be sown to be clean and free from weeds, at the appropriate moisture level.

In the main crop maize cultivation, after the pre-crop harvest,the field should be plowed at a depth of 8-10 cm with a plow while the field is in proper temper, then a second plowing should be made at a depth of 18-20 cm in autumn. If a significant level of weed growth is observed in the field after plowing, it should be plowed with a cultivator and these weeds should be cut. When the soil pans in spring, the field should first be cultivated with a cultivator at a depth of 10-15 cm and prepared for sowing. Deep plowing should be avoided in the spring, which will cause loss of soil moisture and thus loss of temper, such deep plowing should be done immediately after the pre-crop harvest while the soil is in shade annealing.

In second crop maize agriculture, the field is plowed, disc harrow and spring harrow are pulled after the preliminary harvest. If there is no weed problem, duplication can be made by pulling a disc harness perpendicular to each other. In order to prepare a good seed bed, pre-plant harvest should be done as close to the soil surface as possible.

Sowing

The issue to be considered in determining the maize sowingtime is the soil temperature. For a good germination, the soil temperature is required to be at least 8-10 ° C, and it is known that germination and emergence of seeds are faster. Soil temperature is not a factor in second crop maize sowing. Maize sowing should be done as early as possible in order to benefit from winter and spring outflows.

Maize sowing is done by sprinkling the prepared field with a maize seed drill or by hand. In sowing with the machine, the fertilizer in sowing increases the productivity of the summer with sowing. The distance wide rows is 70 cm, and the distance narrow rows varies between 12-20 cm, although it varies according to the planting purpose (grain-silage). Adjusting the sowing frequency correctly will increase the yield of the product, and the answer to the wrongly preferred sowing yield loss should not be forgotten. It is stated that maize plants that are planted frequently will be taller than they will compete in terms of light and material, which causes a decrease in the length of the ear, the number of grains in the ear, and the grain weight in the ear (Sonmez, 2000).

Figure 1. Pneumatic maize drill and combined pneumatic maize drill

It has been reported that the highest yield of silage and hay inmaize production is obtained from a distance of 10 cm narrow row, and the stem thickness and dry matter ratio increase with the increase of the row distance (Tas et al., 2016).

Proper planting depth is related to soil moisture. Sowing depth can be adjusted as 5-6 cm in well-prepared soil with moist seed bed.In cases where soil moisture is insufficient, the sowing depth can be increased and planted at a depth of 6-7 cm. The planting depth should not be higher than 8 cm in order to obtain a good output and desired yield.

Fertilization

It should not be forgotten before the fertilization that the most correct fertilization process is made according the soil analysis and decided according to the result. The soil samples to be taken from the land where maize will be sown should be analyzed and the amount of fertilizer to be given should be decided according to the result.

Figure 2. Fertilized maize field

Nitrogen, phosphorus and potassium fertilizers should be given before or during planting. In order to mix the fertilizer to be given intothe soil correctly and in equal amounts, the fertilizers should be thrown into the field with centrifugal fertilizer distribution machines before the last tillage before planting and mixed into the soil by shallow tillage. In some cases, especially in planting with combined seed drills, it can be applied to apply the base fertilizer to the plant rows with the planting. In such cases, care should be taken that the fertilizer and the seed do not fall in the same order, and if possible, machines that allow the fertilizer to fall 5 cm to the right or left of the seed should be preferred.

Half of the nitrogenous fertilizers should be given before planting or together with the planting, and the remaining half shouldbe given in the next development stages in a way that they do notcome between the plant leaves. In the fertilization to be made after planting, during the second hoeing, while the plants have 5-6 leaves, the fertilization is made before the hoe and mixed into the soil by hoeing. If the irrigation process is done with the drip system, the upperfertilizer can be divided into a few times with the fertilizer tank included in the drip irrigation system. Although there are many commercial fertilizers that can be used for nitrogen fertilization, it isan important issue to prefer fertilizers according to the soil structure. Ammonium Sulphate fertilizer should be preferred to balance soilacidity in salty and alkaline soils. If the soil character is neutral or acidcharacter, then Ammonium Nitrate or Urea should be preferred.

Regarding the nitrogen doses to be given, Al-Kaisi and Yin (2003) stated that the most appropriate dose is 360 kg ha^{-1} N, Rostami et al. (2008) the optimal dose of 400 kg ha^{-1}, Hammad et al. (2011) stated that the optimum nitrogen dose is 250 kg ha^{-1} N. Celebi et al. (2010) stated that the more nitrogen doses applied in the production of maize for silage, the higher the crude protein ratio, also researchers reported that the highest crude protein rate can be obtained from 200 kg ha^{-1} N application.

Among phosphorus fertilizers, it is the most commonly used triple superphosphate in maize cultivation. If it is recommended to give phosphorus as a result of soil analysis, it should be given beforeor with planting. Idikut and Yildiz (2018) reported that 60 kg ha^{-1} pure phosphorus application would be recommended. Since phosphorus is not easily washed from the soil and accumulates, soil analysis must be done before phosphorus fertilization.

If it is determined that there is a need for potassium as a result ofthe analysis, Potassium sulphate fertilizer should be preferred.

Seed amount and selection

Seed to be used in maize production has an important place. Producers should keep in mind that when choosing their maize seed, they should prefer certified and hybrid maize seeds every year. Care should be taken to ensure that the seed to be preferred is clean, with high germination capability, high output power, and pesticides. Ifthere is a disease in the field where maize will be produced, varieties resistant to this disease should be preferred.

In the selection of the variety, care should be taken to choose the varieties in the FAO number that are suitable for the climate characteristics and production purpose of the region where maize will be cultivated. The most important issue in determining the amount of maize seed is how the product will be evaluated. Since the distance between the grain and silage will change, the plant density will also change. Onthe condition that the distance wide row is 70 cm, it is necessary touse seeds with 5-6 thousand seeds in the narrow row 25 cm, 9-10 thousand seeds in the narrow row 15 cm and 14-15 thousand seeds in the narrow row 10 cm.

Maintenance

Maize plant requires a weed-free field from the moment of its first emergence. Therefore, weed control is important throughout the production season. A good weed control in the first growing stages of the maize increases the yield by about 20-30%. Weeds that grow rapidly and make use of the water and benign substances in the soil faster than the cultivated plant prevent the development of maize by covering the soil surface in the first development stages of the maize. In addition, they retard the development of maize by common to water and plant nutrients in the soil. Weed control in maize is done by cultural, mechanical or chemical methods. Cultural measures; Taking some precautions such as the use of clean seeds and crop rotation practices. In the fight by mechanical means, the processing of the rows and, if possible, the cleaning of the weeds in the narrow row with a hand hoe after the machine-driven intermediate hoe come to the fore.

Chemical treatment against weeds is the most economical method of weed control in maize farming. There are herbicides that can be applied before, after planting or after emergence and can be selected according to the types of weeds seen in the field. The herbicide to be used before planting should be mixed with the soil at least 10-12 cm deep. Herbicide to be discarded before emergence after planting is thrown onto the soil surface and is not mixed. Post- emergence herbicides should be used when the weeds are 2-4 cm.

Hoeing is an important process in the fight against weeds of the maize plant, filling the throat and fertilizing processes. In addition, it helps to reduce water loss in the soil by swelling the soil. Hoeing can be done several times until the plant height reaches 50 cm.

Figure 3. Hoeed maize field

If maize planting is done with a classical old type drill, thinning should be done before the plant reaches 10 cm. In this process, weak, diseased and damaged plants should be cleaned and the distance wide rows should be made suitable. If the sowing is done with pneumatic seeders, there is no need for misfire.

The most important issue in combating maize diseases and pests is to prefer clean, disease and pest-free seeds. The seed to be used against seed and seedling rot must be planted after being sprayed with fungicides. Among the most common pests in mazie, grayworm, young small maize seedlings, millet worm and aphids cause damage in every stage of development. Spraying against pests with appropriate medicines at the appropriate time will prevent yield losses.

Irrigation

Maize needs 700-750 mm of water during the production season. In arid and semi-arid regions where precipitation is insufficient or seasonal distribution is irregular, irrigation emerges as the most important factor to fully reveal the potential of the maizeplant (Gencoglan and Yazar, 1999). The period when maize is most susceptible to drought is just before the flowering period, the flowering period and the grain filling period. Since the increase or decrease in the yield in maize production depends on the variety, the amount of precipitation and evaporation and the water conductivity of the soil, restricted irrigation in maize production in places where water is scarce will not cause a decrease in productivity and will increase water use efficiency (Shaozhong et al., 2000). Maize uses carbon dioxide, sunlight and water more efficiently than C_3 plants, as well as having more water during the growing period and being very sensitive to water stress (Huang et al., 2006).

Irrigation frequency and amount of water to be given vary according to the area where maize is grown, the amount of rainfall andthe water holding capacity of the soil. In addition, an effective and correct irrigation application is economically important. Khalili et al. (2013) reported that the frequency of grain irrigation in maize affectedthe grain yield, and that higher grain yield was obtained with frequent irrigation. Majid et al. (2017) stated that irrigation made three times in maize increased the yield, and that increasing the moisture content of the root zone during the plant development period will have a large share in increasing water use efficiency while protecting water.

Maize fields can be irrigated by sprinkling, drip or furrow irrigation. If pressurized irrigation is available, sprinkling until the plants reach 40-50 cm height, then furrow irrigation method is applied.

Figure 4. Sprinkling, drip and furrow irrigation in the maize field

It is seen that the drip irrigation method has also been applied recently. Although the drip irrigation method seems to have highinitial setup cost, it has great advantages in weed control, water savingand top fertilizer.

Harvest

Maize is grown for grain crops, silage and dry feed. Harvesting for the grain product is done when the ear has yellowed the husks well, when a black stain occurs where the grain is attached to the willow and the grain moisture drops to 30-20%. The second crop maize harvest may coincide with the rainy days of autumn, which prevents the humidity from falling and causes the pre-harvest crop to remain in the field. In second crop cultivation, earlyness should be given importance in the selection of varieties, and the varieties in the low FAO number should be preferred.

The harvesting process is done manually or with a specially adjusted harvester according to the breeding purpose. In grain crop cultivation, harvesting is usually done with combine harvesters andthe grain moisture is required to drop below 18%. Maize harvest to be used as silage is carried out at the end of the milking period of the grains, while the leaves are still green, with special silage preparation machines. The harvest of the maize to be used as dry fodder is done after the cobs are taken while the plant is partially green or by cutting from the bottom together with the ears.

Figure 5. Mature maize ear

Grain moisture is expected to drop 18% or less in the hand- harvest threshing process. Then, these ears are grained and blended byrubbing them together by hand, filling them into sacks and pounding or passing through maize granulating machines.

The most important issue in the storage of harvested maize is grain moisture. The grain moisture in maize to be stored should be below 14%. In the storage of the product with high humidity, heating, mold and deterioration occur.

CONCLUSION

If the farmers who will grow maize pay attention to the specified techniques, their unit area yield will increase and the product quality will increase. In maize production, the yield per unit area can be increased especially with the selection of variety, planting and maintenance operations and the correct irrigation method and amount, which increases the direct income of the farmer making the production.

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