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Onion Cultivation and Production in Iran

Naser Alemzadeh Ansari

Department of Horticulture, Faculty of Agriculture, Shahid Chamran University, Ahwaz, 61357-14891, Iran

Correspondence: **Alemzadeh_ansari@yahoo.com**

ABSTRACT

Native onion cultivars have been cultivated in many regions of Iran. Therefore this plant has numerous genetic, biological, and morphological variations. These variations have led to different reactions under various cultivation conditions in natural and experimental environments (both field and *in vitro*). Among onion diseases, root and crown rot caused by *Fusarium oxysporum f.sp. cepa*, is considered an important fungal disease. *Hylemya antiqua* and *Thrips tabaci* are common pests of onions in spring and autumn cultivation. The main ways of protection against them is by using fungicide and insecticide. For eliminating weeds, Iranian farmers use two systems: mechanical and chemical. A combination of two herbicides axonal (Totril®) and oxadiazon (Ronstar®) had good results for control of both broad-leaf and grassy weeds. But recently the herbicide Goal® alone has shown good control in the elimination of all weeds in the transplanting period. The majority of Iranian onion cultivars have a pungent taste, but foreign cultivars cultivated in Iran are sweeter. Onions' shelf life is short to moderate, thus onion is a strategic plant in Iran. Related to this, a reduction in the number of onions has occasionally been noted in Iranian markets at the end of winter, and recent studies for increasing shelf life have been conducted in Iran to select and increase potassium fertilizers to assess the effect on postharvest quality. Onion consumption is approximately 16 kg per person. Onions are cultivated on 49,957 ha in Iran. The average yield of bulb onion in the irrigation zone is 34,254 kg/ha. One of the main purposes of onion research in Iran is to produce cultivars and hybrids with increased quality and yield.

Keywords: cultivar, disease, environment, population, production, shelf life

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INTRODUCTION

In recent years, the area under cultivation of onion and bulb production has increased in Iran. Farmers have increasingly paid attention to foreign seed cultivars, especially Spanish resources, because the amount and uniform maturity of their yield are greater than local cultivars at production time. Local cultivars are gradually being eroded in a region in which onion is widely cultivated.

Iranian farmers need cultivars which have maximum

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Invited Review

yield and that can adapt to a region's natural conditions. I attempt in this paper to explain the current status of onion and its production conditions in Iran.

ONION IN IRAN

Onion (*Allium cepa*) is a memeber of the *Alliaceae* family. The name of this plant in Persian language is pyaz. Onion originated in Iran and its neighboring countries (Hanelt 1990). This plant is one of the main plants which were collected by the first humans who then began its cultivation and reproduction. Onion cultivation history is over than 5000 years old. It appears that onion was cultivated for the first time in the mountainous and high altitude regions of southwest Asia. The primary location for collecting onion is southwest Asia (around the Caspian Sea). This explains why so many wild *Allium* plants may be found in and around Iran (Fritsch *et al*. 2001). According to Vavilove (1951), the primary center of origin lies in Central Asia (see similar origin for garlic, *Allium* spp.; Garlic and Health Group 2007). The Near East and Mediterranean are the secondary center of origin (Raj and Yadav 2005).

Onion is considered a vegetable and herbaceous drug of people in central Asia. Many scientists, doctors and poets of central Asia and Iran quoted several aspects about onion. Abu-Ali Cina wrote about onion in his book Ghanun: "onion oil helps humans against poor weather conditions; ground onion can eliminate bad odors. Onion juice is good to help cure an eye's disease by rubbing them, while with onion juice is beneficial in the treatment of fever, dropsy, catarrh and chronic bronchitis (Ureva and Kokoreva 1992; Raj and Yadav 2005). Even now, onion plays an importance role in human health, and is good for preventing diseases (Gabler 2003; Heber 2004; Krishnapura 2005).

Onion is utilized in various ways: consumed fresh leaf in salads to add flavor, aroma and taste in the preparation of vegetables, frozen, cooked, pickled, used in factory-made food, dehydration, seed production and sets.

Onion has numerous effects resulting from its vitamins (ascorbic acid, thiamine, niacin and A), antioxidant, protein, and minerals such as riboflavin, phosphorous, potassium, sulfur, and iodine (Bahorun 2004). Also it used in almost all salads and food because its fat produces 45 calories/100 g fresh weight.

Onion production

According to FAO statistics, total onion production in the world was 54,762 Kt in 2004. Onion production in Asia is over than 52% of total global production. Asia's biggest onion-producing country is China producing over than 29.6% of total global production.

The area of cultivated onion in Iran in 2004 was 49,957 ha, 48,764 ha of which is irrigated and 1193 ha is dry farming. Most dry farming is in Gilan, Golastan, and Mazandaran provinces having Mediterranean environmental conditions, and having more rain in winter, but all other provinces have irrigated cultivation. Total onion crops produced in Iran was 168,5449.64 tons, and the average of irrigated and dry farming crops, respectively were 34,550.87 and 17,089.96 kg per ha (**Fig. 1**). The maximum yield was in Bonab City with a production of 139 ton per ha. The average yield loss is 35% in total in Iran. However the average annual consumption per person is approximately 16 kg.

Azerbaijan Sharghi province accounts for 24.8% of production, placing it first while Esfahan, Khorasan, and Khuzestan provinces account for 16.7%, 9.3%, and 8.3%, respectively. These four provinces produce 59.1% of total production. Chaharmahal Bakhtiyari province yields 22 tons (0.002%), Iran's minimum production (Ministry of Jahad Agricultural of Iran 2004).

Growth and development of onion is affected by many factors. The main factors that affect bulb or seed production include: cultivars, sowing date, density, growth method, soil, fertilizers, diseases, pests, weeds, and climatic conditions.

Fig. 1 Onion production (tons) in Iran's provinces.

Iranian onion cultivars and population

Onion is cultivated around the majority of Iran cities, and almost all have city names in which they are grown, such as Azarshahar onion, Shahdad onion, Ramhormoz onion, and Bardseer onion. Onion cultivars and landrace collections from different parts of Iran and stored at the National Plant Genebank of Iran (Benedicts 2002).

The most famous onion in Iran is 'Ghermaz Azarshahar'. Seeds of 'Ghermaz Azarshahar' germinate early and can produce good seedlings. This cultivar is an intermediate day cultivar (Ansari 1997).

'Ghermaz Azarshahar' is cultivated more in Azerbaijan Sharghi province, North of Iran. This onion is cultivated in increasingly expanded regions of Iran, and provides the bulk of Iranian onion bulbs in autumn and winter. Other famous cultivars include 'Ghom', 'Kashan', 'Dorcheh', 'Tarom Esfahan', 'Sefid Kashan', and 'Sefid Kordestan'. These onions have been cultivated since long ago, and are very sensitive to translocation (Ansari 2007a), because formation and development of bulbs or scapes of each of these cultivars depends on temperature and photoperiod, they need to be adapted to specific conditions of that specific region. The maximum growth and development of native cultivars is in the region in which they are produced. Old and native cultivar seeds have been reproduced sexually or asexually. These cultivars are very important since each cultivar undergoes several stages of development. Each native cultivar has relative tolerant to diseases (*Aspergillus nigra*) (Ansari 2007a), pests (*Thrips tabaci*), and is symbiotic with other microorganisms, e.g. the roots of *Allium* are colonized by mycorrhizal fungi (vesicular-arbuscular) of the family Endogonaceae (Kojima and Saito 2004). First stage of domestication of a cultivar is its transmission from a primary region to other, and thereafter to other regions where it is to be cultivated. Onion seed that diffuses to other regions begins to adapt.

Other than Iranian cultivars, which are sown in the south and north of Iran, foreign cultivars have also been sown in the same regions such as 'Texas Early Grano', 'Primavera', 'Texas Yellow Grano' in the south and 'Yellow Sweet Spanish' in the north and central Iran (Dehdari *et al*. 2001; Ansari 2007a, 2007b).

Most Iranian native onion cultivars and populations have white, red, pink, and little brown or yellow scales and entered onion cultivars, such as: 'Texas Early Grano', 'Texas Yellow Grano', and 'Primavara' have yellow scales and other cultivars may have red or white, but entered

Fig. 2 Real flowers (A), seeds (B) and a bulb (C) formed on an inflorescence of cv. 'Behbahani'.

onions may have yellow until orange, although red and white onion exist between theme (Ansari 1997; Massiha 2001). Cultivars with white bulbs had higher tightness, dry weight and soluble solid, soluble sugar and pyruvic acid contents than those with different bulb colour. Cultivars with red bulbs had the highest protein content. Soluble solid content was very significantly correlated with other characters except protein content. Bulb tightness was very significantly correlated with soluble sugar content and significantly correlated with soluble solid and pyruvic acid contents (Yong *et al*. 2004).

One of main important parameters, which is the measure of quality evaluation in onion cultivars is pungency (Lin *et al*. 1995), is associated with enzymatic reactions, and supported by the enzyme allinase (Randle *et al*. 1995). In the process, the flavor precursors produce volatile compounds and pyruvates. The pyruvate content can then be used for the indirect quantification of the pungency property (Anthon and Barrett 2003).

Most Iranian onions cultivars have a pungent taste, and are more suitable for storage, whereas entered onions in Iran markets sweetness taste, more suitable for consumption of fresh, they have short shelf leaves.

One of main characteristics of morphology in onion are the formation or non-formation of a real inflorescence, the number of inflorescences per plant, the number of flowers in an umbel, the number of fertilized florets per umbel, the number seeds per capsule, and weight of 1,000 seed. Seed yield of onion depends on the number of fertilized florets per inflorescences and the number of inflorescences per plant (Dehdari *et al*. 2001). These characteristics are strongly affected by heritability, and by environmental and cultural practices (Edirimanna and Rajapakse 2003; Yamashita and Tashiro 2004). Iranian onion cultivars clearly form a true inflorescence (**Fig. 2A, 2B**), which has fertilized florets and whose color of stamens ranges from yellow to greenish. A less explored theme is the formation of topsets on the inflorescence, which in turn develop into bulbils. Occasionally, instead of the umbel a bulb may form (**Fig. 2C**).

The analysis of variance of one experiment conducted at Tabriz University showed significant differences among varieties for several characters: leaf color and length, texture tightness, onion yield/plant, and number of edible layers but no significant differences were observed for the number of twin onions, bulb diameter or onion dry weight. The significant differences between populations for the majority of characters proved the existence of genetic variation in the Iranian onion germplasm (Azimi *et al*. 2000). The results of another experiment at Esfahan showed that the phenotype and genotype were correlated (**Table 1**; Dehdari *et al*. 2002).

Shelf life of onion bulbs

The bulb is the edible part of the onion which is naturally dormant after the juvenile period under inappropriate environmental conditions (interaction of light, temperature, humidity). After some time, the bulbs will start to grow. An unsuitable time to grow onions is either in hot summer or cold winter. Therefore bulbs are the reserve organs of the onion naturally designed to maintain it for a long time (Brewster 1994). Different studies have been carried out on the physiology of onion dormancy. During the storage period the amount of carbohydrates were stored in an onion bulb changes with storage temperature. Glucose, fructose, and sucrose constitute the major proportions of total carbohydrates, averaging 28%, 24% and 10%, respectively. Invertase activity increased progressively after 8 weeks to 0.084 and 0.092 nkat/g fw, at 20°C and 10°C, respectively, and then glucose, fructose, and sucrose contents increase

Table 1 Ranges and averages of various phenotypes, and genotype coefficients and general heritability in 20 Iranian onion genotypes.

Characters	Ranges	Populations or cultivars		Average	Various coefficients (%)		
		Maximum average	Minimum average		P	G	GH
Fifth leaf blade length	22.40-42.20	Ghermaz Azarshahar	Local Zabol	32.72 ± 6.87	22.13	11.13	50.29
Leaf ratio after 4 months	2.63-3.94	Sefid Gorgan	Local Boosheher	3.33 ± 0.40	11.94	10.00	84.81
Bulbing ratio after 4 months	1.40-4.70	Local Zabol	Sefid Gorgan	2.66 ± 0.78	29.22	28.32	94.21
Fresh weight plant after 4 months (g)	23.37-104.57	Dorcheh Esfahan	Sefid Gorgan	59.9 ± 25.04	38.94	34.47	95.24
Dry weight plant after 4 months (g)	2.26-11.71	Dorcheh Esfahan	Sefid Gorgan	6.54 ± 2.72	41.83	40.79	95.10
Plant height (cm)	30.71-67.38	Sefid Ghom	Local Gherveh	49.06 ± 11.72	23.28	22.81	96.00
Days number from sowing to emerging	13.5-19.5	Yellow Sweet Spanish	Taram Zanjan	16.09 ± 1.72	10.63	10.25	92.99
Days number from sowing to maturing	132.00-186.25	Sefid Sari	Sefid Khomine	146 ± 17.25	11.82	11.76	99.01
Bulb height (mm)	33.83-63.72	Yellow Sweet Spanish	Local Zabol	42.73 ± 6.45	15.09	14.72	95.01
Bulb diameter (mm)	47.24-81.33	Sefid Aberko	Bedonenam	61.12 ± 9.16	14.98	14.92	99.61
30 plants yield (kg)	1.79-5.80	Sefid Aberko	Bedonenam	3.39 ± 1.11	32.89	31.98	94.53
Total yield (kg/ha)	18361-57222	Sefid Aberko	Bedonenam	33722 ± 9966	29.56	27.57	93.27

Source = Dehdari *et al*. (2002) with permission; translated into English by the author. P = phenotype; G = Genotype; GH = General heritability.

(Benkeblia *et al*. 2004).

During dormancy break in onion bulbs, the respiration rate (RR) O_2 of sprouted onions was 52% higher than the initial RR A "peak" of soluble sugars (glucose, fructose and sucrose) observed in cold-treated bulbs (from 9 to 19 mg/g fw) after three weeks. In the control bulbs, a similar peak was observed after 6 weeks (Benkeblia and Shiomi 2003; Benkeblia *et al*. 2004; Grevsen and Sorensen 2004). Onion bulbs accumulated fructans, and higher fructan concentrations in bulbs are associated with higher pungency, longer dormancy, and greater onion-induced antiplatelet activity. Highly significant ($P<0.001$) differences among the dry weight between differences among parents and families for glucose, fructose, sucrose, and the fructans 1-kestose, neokestose, and (6G,1)-nystose. Fructan concentrations showed significant ($P<0.05$) phenotypic correlations with each other and with sucrose, pungency, and onion-induced antiplatelet activity (Havey 2004). The cultural management (weed control, choice of variety, control of downy mildew (*Peronospora destructor*) and harvest practices affect the storage life of bulbs (Roos and Fouyer 2005). Moreover, diseases (rot of onion bulbs is mainly caused by *Botrytis* sp., *Aspergillus* sp., *Fusarium* sp. and bacteria), sprout (use of new low-sprouting cultivars, and early harvest at 20-50% "top fall-down", gave less and slower sprouting in onions after long-term storage. Early harvested onions had a higher dry matter content than late harvested onions. Refrigerated cool storage at 1°C for 8 months resulted in ~5 times lower initial rate of sprouting than storage at 5°C) or root production (rooting in bulb onion was reduced by maleic hydrazide but the effect by low temperature was inconsistent) of the bulbs proved to be the main factors affecting storage life (El-Otmani *et al*. 2003; Grevsen and Sorensen 2004; Lee *et al*. 2004).

Temperature is the most influential parameter in the storage period of bulbs. The best temperature for the sprouting of bulbs is between 10°C and 15°C (**Fig. 3**) at which bulbs sprout faster than other hot or cold treatments (Abdalla and Mann 1963). After sprouting, the leaves of the bulbs, which have been kept under 15°C, become longer and thus the leaves grow faster than those bulbs kept under 30°C. So, the sprouting of bulbs does not behave in the same manner as other physiological processes; that is, an increase in temperature does not induce bulbs to sprout (Brewster 1994). Furthermore, sprouting was inhibited at high storage temperatures (30°C) as a result of a significant reduction in the relative growth rate of sprout leaves within the bulbs, and onions almost became dormant (Ramin 1999).

Temperature and RH are two important factors to maintain bulbs for a longer time. Methods of harvesting, curing and keeping bulbs have developed tremendously over the last 20 years. Today, bulbs can be kept after harvest at a depth of 3 m for months. For safety bulbs need load-bearing walls and ducting plus under floor ventilation to force fan-driven (Brewster 1994). Two methods are used to store bulbs.

Fig. 3 Onion bulbs sprout in cold storage.

The first is by keeping bulbs at a low temperature. In this method, the temperature should not be lower than 2°C because of the danger of frost-bite. In the second method, bulbs are kept at a high temperature (above 28°C). This method is unique in hot areas. Due to the high cost of electricity, keeping bulbs in cold storage is not often recommended. Physical conditions such as temperature and water vapor play a role (Currah and Proctor 1990). The growth of the inner roots of the bulb and cellular volume of the inner cortex enlarges during root contraction; changes in bulb shape, expansion, skin cracking, increase in the ability to direct water vapor, and loss of water rate of the bulbs also affect sprouting. The sprouting of bulbs causes both heat production and an increase in respiration rate, in CO_2 levels, and in water vapour (Burton 1982). Decay in bulbs caused by diseases increases the rates of loss of water and respiretion of the bulbs. An increase of water in the environment caused by the increased respiration rate of the bulbs automatically causes an increase in temperature of the storage environment. After a certain period of time, the rise in temperature caused by the additionally produced RH enhances the need to use air conditioning. High RH and temperature increase the possibility for pathogens to multiply. Under hot storage conditions, the amount of decay caused by pathogens such as *Aspergillus nigra* increases (Tyson and Fullerton 2004).

Bulb losses during storage amount to >35% in Iran (Saffarian and Midmore 1994).

Nitrogen fertilizer affects the total soluble solids (TSS) and dry weight (DW) of the bulbs qualitatively in both a positive and significant manner while increasing the nitrogen fertilizer rate up to 120 kg/ha increased the TSS and DW of the bulbs and aerial leaves. Nitrogen fertilizer at 160 and 200 kg/ha decreased TSS and DW. Nitrogen fertilizer (when applied at more than 40 kg N/ha) negatively affected the firmness of the bulbs and the percentage weight loss during storage and caused an increase in sprouting. There was no significant interaction between the nitrogen fertilizer rate and cultivar. Cv. 'Sefid Kashan' performed better than two other cultivars ('Topaz' and 'Ghermez Azarshahar') and is recommended for Karaj's environmental conditions when nitrogen is applied at 80-120 kg N/ha (Kashi and Frodi 1998).

Onion sowing date

Onion is considered as a cold climate crop. Depending on location and environmental conditions the sowing date changes throughout the year. In mountainous and high altitude regions which have a cold climate, sowing date and crop harvesting are in spring and at the end of summer, respectively. But in the southern provinces of Iran where many plains occur, the sowing date is from the end of summer to the middle of autumn (Persian Gulf side and Amen seaside, and the plains area), but the harvesting date is from the middle of spring to the beginning of summer.

Density

The results of an experiment which we performed in winter to evaluate the effects of density on the growth and development of bulb diameter in Khuzestan, Iran indicated that growth dynamics of bulb expressed difference in bulb diameter when grown at various densities 45 days after transplanting seedlings. These differences increased constantly until harvesting time resulting in a 2-fold higher average diameter of bulbs grown at a density of 40 plants/m^2 as opposed to 85 plants/m^2 (Ansari *et al*. 2000). Bervester (1994) believed that bulb diameter can be controlled by density. For example, for plants that can be used for sowing the following year the density of seedlings is recommended at 1000-2000/m^2 while the most suitable density for producing big bulbs (jumbo-size) is between 25-50/m^2; for bulbs used for home cooking the density should be 50-100/m^2. Various densities cause changes in the bulb formation index.

When the bulb formation index, which calculated from the division of diameter set to diameter neck, reaches 2, then the bulb is said to truly begin to form. The maximum and minimum bulb formation index occurred at 40 and 85 plants/m^2, respectively. At a high density (85 seedlings/m^2) right up until harvesting time bulb formation did not begin and dry matter accumulated slowly. This may be since plants competed for light and nutrients. At the highest density, plant height and length of the biggest green leaf were superior in value to the same characters at other densities, but at low density, leaf numbers and dry matter accumulation were more than at high density. By increasing the density, competition among plants for acquiring light and nutrients increases. Moreover, dry matter accumulation in each bulb decreases and formation of the bulb is delayed. All of these lead, ultimately, to a late maturity in the yield. Various density levels affected the yield of bulbs and weight plants were significant (Afshar Manesh and Khodadadi 2007). Maximum and minimum total bulb yield and total plant yield occurred at high and low density, respectively. These results indicated that a positive correlation exists between density and total yield. This also means that with increasing density there is an increase in the total plant yield and total bulb yield. The total plant yield (kg/m^2) and total bulb yield (kg/m^2) can be calculated by the following formulae:

Total plant yield (kg) = 1.6 + 3.75 log (density/m^2)

Total bulb yield (kg) = 0.312 +1.6 log (density/m^2)

Also there exists a negative correlation between the fresh weight of the plant and that of the bulb, both of which can be calculated as follows:

Fresh weight of plant (g) = 144.83-0.954 (density/m^2)

Fresh weight of bulb (g) = 95.83-0.673 (density/m^2).

Bulb production methods

Onion bulbs can be produced by seed, transplanting, and set. An important method of bulb production is transplanting in many northern and central provinces of Iran. The main advantages of transplanting include: early maturity yield, little use of machines, high yield with high quality. Transplanting results in a better control of weeds then by seeding but it requires more labour than others methods.

Seed is directly sown in regions which have a wide, monotonous area and much agricultural machinery. This method is used in the southern provinces of Iran, especially in Khuzestan and Kerman, because early production is very important.

Bulb production by sets or mini-sets is not much used in Iran. These methods are in a primary experimental phase because resistant cultivars to bolting for each region have not yet been found.

Growth and development of onion bulbs depends on the production method (**Fig. 4**).

Fig. 4 Bulbs placed by set (left) and transplanting (right) methods.

Flowering and fertilization

Flowering is one of the prerequisites for producing seed and this stage is believed to be one of the important stages for producing pure vegetable seed. At the bulb production stage the formation of a scape in onion is undesired (Brewster 1994). Therefore, recognition of flowering physiology and its relation to vegetative growth and bulb production are important. The main factors that affect onion flowers include temperature, photoperiod, cultivar, vernalization period, management practice, and growth and development in the field.

Optimum temperature for onion's vernalization depends on cultivar. For example, optimum temperature for stimulation African cv. 'Bao' is 15-21°C while the optimum temperature for Russian cultivars is 3-4°C. The required period of vernalization also depends on cultivar. For example, Japanese cvs. 'Sappariki and Imai-wase' can be stimulated within 20 days at 9°C, while cv. 'Senshoki' needed 30-40 days to stimulate 50% of seedling. Others factors that effect the vernalization of onion plants include: seedling age, field and store temperature, and photoperiod (Brewster 1994; Ansari 1997).

In one experiment in Kabootar Abad Research Station of Isfahan, Iran, for two growing seasons (1998-99 and 1999-2000). Treatments included four planting dates (22 September and at 15-day intervals thereafter), and three intra-row spacings (10, 20, and 30 cm). Planting dates affected the number of umbels/m^2, capsules per umbel and seeds per capsule significantly. As a result, the first and second planting were better than the third and fourth planting dates and seed yield and umbels/m^2 increased significantly as the intra-row spacing decreased from 30 to 10 cm. The means of capsules/umbel and 1000-seed weight were reduced in the 10-cm plant spacing compared with the other treatments. Among the yield components, umbels/m^2 contributed the most to seed yield. Planting dates and plant spacing did not have significant effects on the percentage seed germination. Seed germination rates in the first and second planting dates were higher than the third and fourth, but plant spacing did not have any significant effects on this trait (Aminpour and Bak 2004).

Onion seed production methods

Onion seed can be produced by two methods. The first is by "seed to bulb to seed": in the first growth season, plants produce mature bulbs, which need a period of dormancy. The mother bulbs, if vernalized during this period or during the second growth season, can produce a scape and seeds. An advantage of this method is selecting plants which are adapted to the region. Disadvantages are that two cultivation seasons and many workers are needed, and this method can not be used for onion bulbs which have a short shelf-life. This is the primary method used for producing seed in Iran.

The second method is named "seed to seed": onion seed is produced from seed sowing to seed production in the same cultivation season. In others words, onion plants grow in the fall, develop, vernalize during the winter, pollination, and produce seeds within one cultivation season. This method is mostly used in developed countries (Netherlands, USA and UK) (Brewster 1994; Voss e*t al*. 1999) which have cultivars with known genetic resources. The advantages of this method is that many seeds are produced so few workers are needed; this method can be used for onion bulbs which have a short shelf-life. However, plant production by this method, prior to bulb formation, produces a scape and these plants are unable to adapt to regional conditions in autumn sowing. These cultivars must produce bulbs in these locations, but this plant can be vernalized in periods of chilling in autumn and winter, and produce scapes. These cultivars may be able to adapt by changing the sowing date.

Harvesting

A suitable method of harvesting, transporting, sorting, grading and packaging onion bulbs differs depending on the weather condition of each region, cultivars, and date to maturity. Under dry and warm meteorological conditions curing (curing onion bulbs is an important practice directly following harvest, in which the external layers of the skin and neck tissue are allowed to dry out prior to handling and storage.) and packing bulbs is naturally performed in the field but in temperate regions, drying, curing, and packing bulbs is artificially performed (if forced heated air is used for curing onion bulbs, one day or less at 35 to 45°C (95 to 113°F) and 60 to 75% relative humidity is recommended) and bulb quality over a wide area depends on it. Curing bulbs is necessary because pathogenic agents are unable to enter the bulb from neck (Currah and Proctor 1990). Drying them improves bulb color and does not produce cracks in dried scales (Wright and Grand 1997). Older methods of harvest include pulling bulbs from soil without cutting their soil-embedded parts and then arranging them on a line until dry and cure them in hot fields exposed to intense sunlight. Since bulbs must be protected from the effects of direct sunlight one layer of leaves is used to cover the external part of the bulb. Since scales and other external parts of bulb may be burned by the sun's radiation, if this protective part is killed, it is possible that bulbs decay. Bulb can be arranged in one or two lines after cutting leaves off. After one or two days when the leaves dry they may be cut from the bulb. Healthy bulbs are harvested at the stage of maturity when the zone near their necks is dry. In regions with dry weather, leaves can be removed when the bulbs are harvested, and the bulbs are placed on lines until they are prepared for packing and sending (Jones and Mann 1963). If the bulb's skin is wet at harvesting time, in particular if their epithelial leaves are decayed, it is possible that the growth of the fungus *Botrytis cinerea* can damage bulbs in dark. Moreover, moisture causes the decay of inner parts, therefore, successful protection and storage depend on bulbs being dried in the field in a temped region.

Soil

Onion roots seldom divide and they develop very superficially, therefore for successful production they need deep and fertile soils, with free drainage, absence of persistent weeds and the presence of organic matter. Soil pH in the range 5.8-6.5 is usually recommended even though onion can be grown in a wide range of soils. For raising onions in a nursery, sandy loamy soil is preferred.

Onion is regarded as a plant susceptible to salts during seed germination and establishment. A study was conducted to evaluate the tolerance of 10 Iranian onion populations to NaCl at the seed germination and seedling growth stages, to determine critical NaCl concentrations for these populations and to select NaCl-tolerant seedlings. The populations differed significantly in the percentage of seed germination rate, fresh and dry weights of the seedlings, and the length of radicles and whole seedlings ($p<0.01$). This experiment indicated that the salt tolerance of various populations differed during germination and seedling growth (Massiha *et al*. 2002). Another experiment, conducted to investigate the effects of salinity and drought stress on the growth and biochemical composition of 4 onion cultivars, i.e. 'Dessex', 'Texas Early Grano' ('Texas'), 'Dehydrator' and 'PX492', showed that NaCl and drought treatments significantly reduced stem dry weight (SDW) and root dry weight (RDW). Cvs. 'Texas' and 'Dessex' produced the highest and lowest SDW, respectively. NaCl significantly increased Na^+ uptake, but reduced K^+ uptake in the shoots and roots and Ca^{2+} uptake in the roots. NaCl and $CaCl_2$ significantly alleviated the deleterious effects of NaCl, such that SDW, RDW and K^+ contents increased, while NA^+ and sugar contents in the shoots and roots decreased. Both salinity and drought increased the total protein contents in the shoots of 'Texas', but either decreased or had no effect on the total protein content of the other cultivars. Salinity increased the total protein content of the roots, while drought had not effect. Changes in the proline and sugar content in both shoots and roots exhibited no specific pattern. Of the different biochemical properties evaluated, the total protein content of shoots exhibited a positive significant correlation with SDW under both stresses, indicating that this biochemical property may be used in screening drought- and salt-tolerant onion cultivars (Arvin and Kazemi-Pour 2002).

Effects of fertilizers on growth and development

Onion is classified as a salt-sensitive crop (Chang and Randle 2004), and for reaching a maximum crop, the density and primary size of plants must be considered, and the primary nitrate application rate must decrease. The first time fertilizers are mixed with soil before sowing seed, and the second time, when the height of the plant is ~l0 cm, the same amount of fertilizer is applied. The rate of nitrogen used in the field depends on the amount of nitrate present in the soil before cultivation. For production of spring bulbs in Iran, the available total nitrogen should exist in the upper 60 cm of soil, and fertilizer should be added at 120 kg/ha (Kashi and Frodi 1998). If nitrogen fertilizer application increases, the nitrate content of the bulbs increases. Nitrate accumulation is lower in leaves than in bulbs (Rostamfrodi *et al*. 1999).

Incorrect application of fertilizer affects the crop quali- and quantitatively, and excess nitrate remains in the bulb and in the soil at harvesting time (Westerveld 2003). This excess contaminates peripheral and deep soil water and causes the salinity of soil in dry areas (Hamilton 2004; Platts *et al*. 2004). Therefore methods that improve the efficiency of fertilizer absorption in the first round of cultivation are encouraged. For reducing the amount of nitrogen applied, ammonium phosphate liquid fertilizer can be used as a starting fertilizer at the time of cultivation; fertigation fertilizer may also reduce the fertilizer requirements of the crop by as much as 40% compared to broadcasting without significantly affecting the yield (Neelam and Rajput 2003). This method can improve the efficiency of absorption of phosphate and nitrogen, because the rate of growth immediately after the seedling emerges depends on the rate of nutrition in the soil solution. After this stage, an optimum nutrition level in the soil solution is needed to reach a peak in the growth of onion roots. Some nitrate ammonium must be added to 20 kg nitrogen starter fertilizer. This will increase the crop yield, thus compensating for any nitrogen deficiency and causing the crop to produce 33-52% more biomass then seedlings in which only fertilizer is received at first.

Climatic requirements

Onion can be grown under a wide climatic range, usually the cool season, but it grows well under mild climate without extreme heat, cold or excessive rainfall. The main climatic factors that affect the growth and development of onion include: available water, photoperiod, and temperature.

Available water

Seed germination, growth and development of leaves, the bulb, and sprouting bulb are affected by available water in the soil or humidity of the environment. The water an onion plant needs in the soil is provided by rain or irrigation. In Gilan, Golestan, and Mazandaran provinces much vegetable cultivation such as onion is grown by dry farming but in other provinces water must be provided. In regions which have a wide area of cultivation, irrigation is by furrows but in mountainous regions and small areas, irrigation is in plots. Other methods of irrigation are not commonly used in Iran.

Photoperiod

Bulb production occurs in long photoperiods, but the reaction of cultivars to photoperiod differs (Garner and Allard 1920). Onion cultivars are classified into short, intermediate, and long-day types based on the minimum photoperiod that an onion bulb requires for its formation. This classification has more application for bulb production and onion cultivar improvement in various latitudes, for bulb production, usually short day onion cultivars are grown less than 30° latitude, intermediate between 30° and 38°, and grown at latitudes greater than 38° are long-day types (Tarakanov and Mamadu 1990; Rubatzky and Yamaguchi 1997). The idea is that either bulbing or bolting of the plant is controlled by the balance between hormones. One of main external stimulators of hormone production in bulb formation is photoperiod; therefore with increasing photoperiod, bulb formation rate will be faster. And with decreasing photoperiod, bulb formation rate will decrease (Brewster 1994). If a cultivar is not sensitive to photoperiod induction in a region, it will not be suitable for bulb production in that region. For example, if a long day or a moderate cultivar is sown near the equator, it never produces bulbs. Therefore, because required photoperiod is never prepared for stimulation of bulb production, it does not form a real bulb. In addition, if a short day onion cultivar is sown at great latitudes during spring, the effect of long day length on leaves results in the rapid reception of photoperiod signals which then stimulate bulb production by phytochrome; consequently, small and weak plants having only two or three leaves were stimulated to induce bulbs, resulting in the rapid production of very small bulbs (Currah and Proctor 1990; Ansari 1997; Mettananda 2003). Short day cultivars are suitable where onion is cultivated in autumn, such as south Iran provinces and where onion bulbs are harvested in mid-spring and the beginning of summer. One important foreign cultivar that is cultivated in south Iran is 'Texas Early Grano' but different local cultivars are used in different cities, such as 'Ramhormozy' in Khuzestan, and 'Shahdad' in Kerman. Moderate day cultivars in north and central Iran are sown after the cold end of winter and bulbs are harvested at the beginning to end of summer such as 'Ghermaz Azarshahar', 'Sefid Kashan', and 'Sefid Kordestan'. Because maximum day length in Iran is not more than 14 hours, Iranians do not use long-day types.

Temperature

Many fundamental aspects of what is known about the effect of temperature were discovered in a classic study by Ansari (1997) who followed the growth and development of three onion cultivars ('Pusa Red', 'Texas Early Grano', 'Ghermaz Azarshahar') which grown in latitudes as low as 40°. Results are summarized below.

Temperature affected the growth and development of onion at all steps, especially germination, growth and development of leaves, and in the production of bulbs or scapes. Growth and development of cultivars are different at low and high temperatures. Onion cultivars produce a scape at relative low temperature (1-17°C, optimum 8-12°C), but the required period and bud numbers which produce a scape are different in various cultivars and at different seedling ages. At a relatively high temperature (22-25°C), 'Ghermaz Azarshahar' and 'Texas Early Grano' cvs. produce only bulbs but cv. 'Pusa Red' produce both a bulb and a scape. At a relative low temperature (8-12°C) the growth of bulbs differs in various cultivars. For example cv. 'Texas Early Grano' produced bulbs but cvs. 'Ghermaz Azarshahar' and 'Pusa Red' cultivars did not. As the age of the seedling increases before translocation to a relatively low temperature, plants produce a scape more rapidly.

The resistance of a cultivar to producing a scape depends on the cultivar and some researchers believed that autumn cultivars have more resistance than spring cultivars.

Growth and development regulators

Bolting in onion reduces yield and quality of bulbs. To control bolting chemically, a glasshouse experiment was conducted using 'Texas Early Grano' which is widely cultivated in subtropical areas of Karman Province. One study showed that Paclobutrazol reduced bolting, reducing sugars, soluble proteins and shoot length but increased leaf chlorophyll, proteins, sugars and bulb weight with no effect on shoot dry weight. Although ethephon reduced bolting, shoot growth, sugars, proteins and leaf chlorophyll and increased maturity index, sugars and proteins in bulbs, it had no effect on bulb yield. Cycocel increased bolting, sugars, proteins, chlorophylls and dry weight in shoots but had no effect on shoot length, leaf chlorophyll, sugars and protein in roots and bulb weight. Cycocel also reduced sugars and protein in bulbs. Mixtures of cycocel and ethephon reduced bolting, leaf chlorophyll, shoot length and dry weight but had no effect on bulb yield and other characters measured (Arvin and Banakar 2002).

DISEASES AND PESTS IN ONION

The majority of disease pathogens and pests attack onions in Iran. In this section, the main diseases and pests are discussed. Important viruses have been identified as three elongated viruses from *Allium* species in Tehran province, Iran. Analyses by DAS-ELISA and immuno-electron microscopy using polyclonal and monoclonal specific antisera available against German *Allium* virus isolates revealed the presence of 3 elongated viruses, namely, *Onion yellow dwarf potyvirus*, *Garlic strain* and *Leek yellow stripe potyvirus* from both onion and garlic samples. A new mite-borne filamentous virus was also identified from garlic. These viruses were mechanically transmissible and could produce chlorotic local lesions on *Chenopodium quinoa* indicator host plants (Shahraeen 1998).

In Greece an experiment showed that *Shallot latent virus* (SLV) was found only in two areas (Evros and Theva) and in onion fields planted with imported propagative material, from Iran and China (Dovas *et al*. 2001).

Most of the viruses are symptomless and do not cause disease. Two, *Onion yellow dwarf virus* and *Leek yellow stripe virus*, cause serious diseases (Brewster 1994). *Tomato spotted wilt virus* (TSWV) and *Iris yellow spot virus* (IYSV) infections were serological, causing onion plants to exhibit stress symptoms such as tip dieback, necrotic lesions, chlorosis or environmental damage. A population of *T. tabaci* known to transmit IYSV (onion isolate) did not transmit any of the studied tospoviruses (Vozelj *et al*. 2003; Nagata *et al*. 2004).

Nematode pests

Nematodes are small worms, which form a main essential part of the soil fauna. Sixty-eight species of nematodes are associated with the roots of crop alliums. A small percentage of nematodes cause damage and the main pest is *Ditylenchus dipaci*. The life-cycle of *D. dipsaci* takes about 20 days in onion plants at 15°C. Females lay 200 to 500 eggs each. Fourth-stage juveniles tend to aggregate on or just below the surface of heavily infested tissue to form clumps of "eelworm wool" and can survive in a dry condition for several years; they may also become attached to the seeds of host plants (e.g. onions, lucerne, *Trifolium pratense*, faba beans, *Phlox drummondii*). In clay soils, *D. dipsaci* may persist for many years. Cool, moist conditions favour invasion of young plant tissue by this nematode (Brewster 1994).

In general, this nematode causes swellings and distortion of aerial plant parts and necrosis or rotting of stem bases, bulbs, tubers and rhizomes. Penetration of onion leaves by *D. dipsaci* causes leaf deformation and leaf swellings or blister-like areas on the surface. The leaves grow in a disorderly fashion, often hang as if wilted and become chlorotic. Young plants can be killed by high infestations.

The inner scales of the bulb are usually more severely attacked than the outer scales. As the season advances the bulbs become soft and when cut open show browning of the scales in concentric circles. Conversely, *D. dipsaci* on garlic does not induce deformation or swellings, but causes leaf yellowing and death (Netscher and Sikora 1990).

Bacterial disease

Many bacteria cause rotting in storage onion bulbs, important where onion bulb is stored at high temperatures. Bacteria tend to infect scales but do not move easily to them; therefore, the interleaving of decaying and sound scales in transversely sliced bulbs is characteristic of bacterial disease. *Erwinia* spp. and *Lactobacillus* spp. are part of the leaf microflora of field onions which may enter bulbs through the neck in wet weather, or via wounds caused by pests like nematodes or onion fly (*Delia antiqua* Meigen).

Pseudomonas allicola, *P. cepacia*, and *P. acruginosa* have been identified as causing water-soaked storage scales within the bulb in which the outer fleshy scales become slimy with a sour taste, and a brown rot of stored bulbs some weeks after harvesting. These are pathogens found in the soil in onion fields and probably gain entry to plants following abrasion damage during wet weather. However, too little is known about the biology of these pathogens, in particular the sources of inoculums, the mode of infection and the conditions favoring infection, for rational control strategies to be devised (Brewster 1994). But monoculture, agronomic management, presence of other diseases and insect pests, susceptible cultivars and favourable climate cause the development of disease in bulb onion (Martinez 2000).

Reactions of onion cultivars differ depending on the bacterial disease. Several onion cultivars demonstrated good shelf life characteristics and more resistance against these diseases (Gowda *et al.* 2004).

Fungal diseases of roots

Several fungal pathogens cause root diseases in onion such as *Sclerotium cepivorum* (white rot; Hovius and Goldman 2004), *Phoma terrestris* and *Fusarium solani* (pink root; Cramer and Corgan 2003; Kamlesh and Sharma 2003), *Fusarium oxysporum f.sp. cepae* (Fusarium basal rot; *Ozer et al.* 2004), *Urocystis cepulae* (onion smut; Nicola *et al.* 2004), *Sclerotium rolfsii* [*Athelia rolfsii*] as a new causal agent of southern blight (Vitale *et al*. 2004), *Fusarium oxysporum* damping off and basal rot, *Alternaria porri* purple blotch, *Stemphylium vesicarium* (blight; Tiwari and Srivastava 2004), all of which are soil-borne, root-infecting fungal diseases that attack the roots of onion plants. The symptoms of disease, as might be expected from the destruction of roots, are those associated with water or nutrient stress. Leaves lose turgor, wilt, become yellow and ultimately die, and plants become stunted and may collapse. The symptoms are aggravated by drought. Early attack can result in the failure of emergence or the collapse of seedlings. All soil-borne diseases can be spread on infected planting material and by anything that moves in infected soil from place to place. Their control is difficult because, being in soil, the pathogens are inaccessible to treatment chemicals or antagonistic organisms. There is a correlation between the population density of pathogen propagules in soil, the inoculum density, and the severity of disease. Therefore, any measures, such as crop rotation or the removal of infected plants, which reduce the inoculum density, are helpful in control. However, some of the pathogens have extremely long-lived resting bodies, so that control by rotation is ineffective. Also the development of disease is dependent on environmental conditions, in particular temperature, so sometimes crops are grown only during seasons when temperatures are not conducive to disease (Brewster 1994).

Onion white root rot, caused by *Sclerotium cepivorum*, disease incidence was reduced from 58% in early sown high density onions grown without fungicide application, to 0.3% in late sown low density onions grown with a single fungicide application. Differences in disease incidence of up to 70% have been recorded between cultivars. Reducing disease levels from 75 to 11% and increasing yield from 15 to 44 t/ha when compared to onions grown in untreated soil and without fungicide application. Another control option being investigated is the use of *Eucalyptus* leaf mulch which has shown a very high level of control in pot studies (Dennis 2001). *Trichoderma* spp. isolates against onion white rot significantly reduced *S. cepivorum* infection and increased the yield of onion compared with the untreated control (Metcalf 2002).

Bulb rot in Iran

The pathogens which infect the root and bulb tissues of onions growing in Iran include: *Fusarium oxysporum*, *F. acuminatum* [*Gibberella acuminata*], *F. solani*, *F. equiseti* and *Sclerotium cepivorum* (Peyghami 2001). Root and crown rot, caused by *Fusarium oxysporum f.sp. cepa*, is considered an important fungal disease. *F. oxysporum*, *F. solani* and *F. acuminatum* [*Gibberella acuminata*] were consistently isolated from roots and basal parts of infected onion plants collected throughout East Azarbaijan, Iran. The pathogenicity of all 3 species on onion was confirmed under greenhouse conditions. *F. oxysporum* was more prevalent than two other species (Behroozin and Assadi 1994). In one study, the inhibitory effect of *Bacillus cereus* (isolates 22 and 52), *B. subtilis* (isolate 126), *Pseudomonas fluorescens* (isolates 48 and CHAO), benomyl fungicide and a combination of isolates CHAO and 22 and isolate 52 and benomyl were investigated on disease development under field conditions. Isolate 126 was the most effective antagonist with regards to crop yield but other treatments, despite showing a significant effect on plant growth factors, were less effective in increasing crop yield (Sharifi Tehrani *et al*. 2004).

The antifungal activity of onion on two important dermatophytes, *Trichophyton rubrum* and *T. mentagrophytes*, with special reference to morphological aspects was studied. Growth of both fungi was found to be strongly inhibited by aqueous onion extract (AOE) in a dose-dependent manner. The extract showed fungicidal effect for both fungi at concentrations >3.12% (v/v). The fungus *T. mentagrophytes* was more affected by onion than *T. rubrum* at all concentrations used. Morphological effects of onion exposure were examined in correlation with fungal growth. Corresponding to the growth inhibition, light and electron microscopy observations revealed morphological anomalies in hyphal compartments. The results demonstrated that AOE targets the cell membrane of the fungi by breaking down both the inner and outer membranes with consequent extrusion of materials into the surrounding medium. Cytoplasmic membranes and other membranous structures of organelles, such as nuclei and mitochondria, were also disrupted. In relation to fungal growth, morphological alterations occurred to a less extent for *T. rubrum* than *T. mentagrophytes*. The hyphae of *T. rubrum* were found to be mainly affected by converting to resistant forms, i.e., chlamidospores as a consequence of the phenotype switching response to AOE. Plasmolysis accompanied by an almost complete depletion and disorganization of cytoplasmic structures were found to be the final event which led to cell death. Ultrastructural evidence obtained from this study strongly supports that morphological changes of *T. rubrum* and *T. mentagrophytes* caused by AOE are associated with its fungistatic and fungicidal activities. With respect to the morphological results and the preliminary data on fungal biochemistry, a mechanism of action by interacting of AOE with thiol (-SH) groups present in essential compartments of the fungal cells was postulated (Ghahfarokhi *et al*. 2004).

The effect of *T. harzianum* and *T. viride* (isolated from the mycoflora of the onion rhizosphere) in increasing the growth of onion was studied in a completely randomized design in pots with 12 replications under greenhouse conditions at 21°C with a 12-h light/dark cycle (fluorescent and incandescent lighting). The biological control of *Sclerotium cepivorum*, the causal agent of white rot of onion, was also investigated in this experiment. The addition of *Trichoderma* spp. to autoclaved soil (inoculation of 2/3 of the top soil in the pots with 4% (v/v) inoculum of *T. harzianum* and *T. viride*) significantly increased the growth and fresh weight of onion plants (P=0.01). Biological control of *S. cepivorum* was achieved with *T. harzianum* and *T. viride*, but no significant difference was observed between the two species (Payghami *et al*. 2001).

Fungal diseases of stem and scape

Pathogenic fungi cause various leaf diseases, e.g. *Peronospora destructor* which causes downy mildew (Shynkorenko 2003). The history, prevalence, hosts, symptoms, morphology, biology and control of onion and other *Allium* spp. fungi have been reviewed elsewhere: with special reference to Iran (Assadi and Izadyar 1973); *Alternaria* sp. purple blotch (Tiwari and Srivastava 2004); *Stemphylium botryosum* (*Pleospora herbarum*), *S. vesicarium*, and *Alternaria alternate* leaf blight (Cova and Rodriguez 2003); *Puccinia allii* onion rust (Lupien *et al.* 2004); *Colletotrichum gloeosporioides* and *Glomerella cingulata* leaf twister (Weeraratne 2003); *Botrytis* spp. onion leaf spot (Kohl *et al.* 2003). Damage of onion leaves destroys the stimulus for bulb initiation and delays or prevents bulbing and maturation. Severe attacks on flowering alliums can completely girdle flower stalks: with necrotic tissue, causing their collapse and a total loss of seed production capacity. All these diseases are favored by wet, humid weather, and surface water on leaves for a sufficiently long period of time allows pathogenic spores to germinate and penetrate the host. Field hygiene is important to remove or plough-in infected debris, to prevent spread and carryover to subsequent crops; Rotations should be sufficiently long for such debris to have decayed and disappeared. To decrease humidity, and the duration of leaf surface wetness, wide plant spacing and low levels of N fertilizer can be used to keep Leaf Area Index (LAI) low and to promote free air movement. Several leaf diseases are caused by weak pathogens, and attack is predisposed by leaf damage during cultivation or possibly by herbicides, by other pathogens and pests, and by atmospheric pollutants like ozone. Some of the systemic fungicides have an eradicating as well as a protective action. These must be on the leaf before infection occurs.

Fungal diseases during storage

The main known diseases during storage include neck rot in temperate climate and black mould in tropical and subtropical climates.

A serious disease in temperate zones is neck rot, which is caused by the fungus *Botrytis aclada* (syn. *B. allii*) and *B. byssoidea* (Chilvers 2004). Neck rot causes a soft rot in the neck and upper regions of infected bulbs. A black mass of sclerotia, the resting bodies of the fungus, develops below the dry outer skin on the decaying tissue, and a grey mould of sporulating bodies may also develop on the surface of the decaying fleshy scales. These symptoms usually develop some two to three months after the apparently healthy but infected bulbs are placed in store. The pathogen also invades the inflorescences of onions and can diminish seed yield. Infected seed heads produce seeds which carry the infection. Seed are the primary source of infection. This disease can be controlled by treatment of seed at the time of sowing, fungicide spray in the growth and development period and by increasing temperature above 30°C in storage by blowing warm air over the bulbs.

Fig. 5 Onion bulbs infected by black mould.

Black mould (Aspergillus niger)

Black mould of onions is caused by the fungus *Aspergillus nigra* van Tieghem (**Fig. 5**). It is a high-temperature fungus, with an optimum temperature range for growth at 28-34°C. Warmth and moisture favour development of the disease (Maude *et al*. 1984). Although the disease can occasionally be seen in the field at harvest, black mould is primarily a postharvest disorder and can cause extensive losses in storage under tropical conditions (Thamizharasi and Narasimham 1992). In warm and moist favorable conditions, various onion cultivars have different reaction to *A. nigra*. The shortest and longest storage life are attributed to foreign cultivars such as 'Texas Early Grano', 'G1', 'Texas Yellow Grano' and local cultivars such as 'Behbeheni' and 'Rammhormozy', respectively (Ansari 2007).

Onion pests

Many pests attack onion fields and storage and can cause damage to onion yield and bulbs: mites (*Rhizoglyphus echinopus* and *R. robini* (Acari: Acaridae)) (Ostovan and Kamali 1995), cutworm (*Spodoptera exigua*) larvae (Padua *et al.* 1999), moth (*Spodoptera exigua*) (Rao and Subbaratnam 1999), onion weevil (*Ceutorhynchus suturalis*), onion beetle (*Lilioceris merdigera*), and leaf miners (*Agromyzidae*) (Uczak and Wiewiora 2002). But some pests damage the whole onion field; mainly thrips (*Thrips tabaci*) and onion fly (*Delia antiqua*).

Thrips

Thrips is an important pest of onion production throughout the world. Damage caused by thrips hinders the development of the onion, causing the plant to end its development earlier than usual, so there may be a decrease in crop yield, too. Thrips are slender insects only 2 mm long, and insects accumulate between the young leaf blade and the top of the neck. In this sheltered part of the plant they rasp and pierce leaf cells and feed on the sap released. The resultant air spaces in the leaf cells give the foliage a silvery appearance. They attack in warm regions, especially when the plant is water stressed in hot, dry weather, although the insect may be found in all zones in which onion is grown. The natural enemies of onion thrips can reduce the population only to a small degree. One of the efficient and environmentally friendly protection methods could be the production of thrips-resistant onion varieties (Hudak and Penzes 2004). Natural enemies, including predaceous mites, minute pirate bugs, and lacewings, are often found feeding on thrips (Coviello *et al.* 2006).

In Iran the life cycle of onion thrips was investigated in an insectarium under constant conditions (27 ± 1°C, 57% ± 5 RH and 12:12 h (light:dark) photoperiod). To estimate the duration of different periods of the life cycle and its biological characteristics, individual cages were clipped on the leaves of onion plants. No males were observed during the study and it seems that the thrips has a thelytokous (parthenogenetic) type of reproduction. Eggs were laid inside the plant tissue (endophytic) individually or in masses of 2-3. Durations of developmental stages for the egg, first and second instar larvae, pre-pupa, pupa and adult were 4.18 ± 0.53, 2.08 ± 0.56, 2.11 ± 0.80, 1.25 ± 0.80, 1.25 ± 0.47, and 2.23 ± 0.95 days, respectively. The preoviposition period was 3.60 ± 1.28 days. The mean life time of the adults was 16.15 ± 7.58 days. The mean number of eggs laid per female was 31.63 ± 18.86 and the mean number of eggs per day was 2.04 ± 0.84 (Salmasi *et al.* 2003). In another study the predatory activity of *O. nigra* was studied on cucumber leaf discs containing onion thrips (*T. tabaci*) larvae in the laboratory (26°C and 65 ± 5% relative humidity). The hunting and attack behaviours of the predator and the reaction of the prey to such behaviours were also investigated. *O. niger* at densities of 1 and 4 recorded predation rates of 6.22 ± 1.18 and 8.60 ± 0.76 preys killed per hour; encounter rates of 0.525 ± 0.08 and 0.724 ± 0.029 h^{-1}; success ratios of 0.973 ± 0.14 and 0.852 ± 0.041; and handling times of 4.095 ± 0.672 and 3.006 ± 0.520 larvae/minute, respectively. Of these parameters, the encounter rate and success ratio were significantly higher in densities of 4 than 1. Gut capacity and the rate constant of gut emptying were 0.059 mg and 0.151 h^{-1}, respectively (Baniameri 2003). Insecticides are often used to control thrips. Profenofos is one a commonly used insecticide in the control of *T. tabaci* on spring onion in Iran. Residues of profenofos in spring onion were determined in two different fields under the same conditions. In the first field, onion plants were sprayed with profenofos (40EC) at a rate of 1000 g/ha. Spraying was repeated 2 weeks later. In the second field one spray was performed at the same rate. Spring onion were sampled at different time intervals and analysed for profenofos residues using a GC equipped with NPD detector. In the first field's samples, the residues were 0.097 and 0.025 mg/kg at 2 and 6 days after spraying, respectively. The residues declined to 0.002 mg/kg on the 12^{th} day. Two days after the second spray the residue was 0.27 mg/kg, and reduced to 0.032 on the 6^{th} day. However the residues were not detectable 32 days after the second spray. In the second field, residue levels were 0.193 and 0.043 mg/kg at 2 and 6 days, respectively after spraying. Residues found after 32 days were less than 0.001 mg/kg. The rate of residue decay in the first field was higher than in the second field (Talebi and Ghassami 2004).

Mineral fertilizer application did not increase onion thrips incidence significantly (Gonçalves and Sousa 2004).

Significant correlations were found between presence of leaf wax and susceptibility to thrips that is correlated with foliage color. Accessions with light green color or glossy foliage are more resistant to thrips than darker colored genotypes (Benedicts 2002).

Onion fly or maggot (Delia antiqua)

Onion maggot attacks all vegetable alliums. The most severe damage is into the base of onion seedlings early in the seedling period. They lay eggs and affect plants which become wilted and collapse. When the seedling dies, the maggot migrates to other plants. They can feed on the expanding bulb during later stages of growth. This results in increased rot in bulbs held in storage.

Delia antiqua is a common pest of onions in Iran, causing 80-90% infestation of plants after heavy spring rain and treatment with animal manure. Adults emerge in May and lay eggs in, near or directly on food plants. Larvae enter the stem and leaves of *Allium* spp. Pupation occurs in the soil. Second-generation adults emerge in late June and overwintering occurs in the pupal stage. In the laboratory at 20-23°C, 55-70% RH and LD 16:8, one generation was completed in 35-55 days (Fard 1992).

Others pests which they can infect onion plants include onion weevil (*Ceutorhynchus suturalis*), leek moth (*Acrolepiopsis assectella*), onion beetle (*Lilioceris merdigera*), and leaf miners (Agromyzidae). Statistically significant differences were observed between the tested cultivars ('Rawska', 'Wolska', 'Sochaczewzka', 'Zytawska', 'Hyton F1', 'Hyduro F1', 'Armstrong F1', 'Spirit F1', 'Robusta', 'Red Baron') in terms of the maximum and average percentage of plants infested by them. Most 'Red Baron' plants were infected with *C. suturalis* (maximum -20%, average 5.4%). The strongest infestation by *L. merdigra* was noted in two cvs. 'Sochaczewzka' and 'Zytawska'. Three cvs. ('Red Baron' – 40%; 'Rawska' and 'Robusta' – 33.3%) were considerably susceptible to thrips and relative tolerant cvs. 'Hyton F1' and 'Armstrong F1' showed a maximum of 5%, and an average of 1.2% (Luczak and Wiewiora 2002).

Wild weeds

Onion plants are very sensitive to wild weeds, because morphological and physiological characters of onion plant do not allow competition with them. Weeds affect onion growth and development, and cause severe losses every time they overcome a field. Therefore weed control is the first aim for producing onion. The first step in the control of weeds is by knowing them. Thirty-three weed species of onions in the Esfahan area of Iran have been listed. The dominant species are *Chenopodium album*, *Amaranthus retroflexus* and *Echinochloa crus-galli* (Fatemi 1979). Many ways are used for controlling weeds in the field. The oldest method is mechanical control. It is used in small and mechanical fields, for early-producing yield and for producing poison-free onions. Many herbicides can use for different growth steps. Ioxynil (0.6 and 0.7 kg/ha) controls the broad-leaf weeds such as *Chenopodium album*, *Convolvulus arvensis* and *Amaranthus* spp. This herbicide can not control grass weeds such as *Setaria viridis*. The application of oxadiazon (0.36 kg/ha) controls grass weeds well and suppresses the growth of broad-leaf weeds. Onion yield in oxadiazon and ioxynil plots was shown to be similar. The application of oxadiazon (0.36 kg/ha) along with ioxynil (0.7 kg/ha) controlled both broad-leaf and grass weeds. In this case both weed density and dry weed biomass were also reduced. Onion yield was highest in this treatment and in hand weed control. The control treatment plots did not produce any suitable onion due to competition (Shirzad and Nazar 2003). In this manner Oxyfluorfen as a general herbicide is used in onion fields (Shimi 1998).

TISSUE CULTURE AND MICROPROPAGATION

For improving onion cultivars and producing pure lines haploid plants could be used.

Tissue culture can be used for the propagation of elite and rare material, development of homozygous lines through anther, ovary, ovule, and flower culture (Bekheet 2004).

Onion genotypes showed significant genotypic differences in response to callus production and multiple shoot formation from different explants. Genotypic difference in the regeneration of *Allium* have also been reported by several researchers (Zheng *et al.* 1998; Barandiaran *et al.* 1999; Marinangeli *et al.* 2005). Tanikawa *et al.* (1998) reported significant differences among cultivars regarding plant regeneration efficiency.

Callus induction was observed in all explants (basal plate, apical meristem with basal plate, immature umbel, mature zygotic embryo, and fecundated ovule) of *A. cepa*, irrespective of the growth regulator composition and ratio in the media, although it was low in some treatments. Callus induction was more dependent on explant than on auxin type or concentration. 2,4-D-induced calli from mature zygotic embryos and fecundated ovules were more friable and exhibited lower root differentiation following subculture than those induced by picloram. Callus growth rate showed low variability between treatments, ranging between 100 and 150% mass increase per month. *A. cepa* 'Valcatorce INTA' calli showed a low regeneration potential, averaging 6.6% for all explant-derived calli (Marinangeli *et al.* 2005).

In *Allium* tissue culture, plant growth regulators have an essential role in *in vitro* culture, and the addition of cytokinin can be significant for plant regeneration (Bhaskaran and Smith 1990). MS (Murashige and Skoog 1962) or BDS (Gamborg's BS modified medium) supplemented with a cytokinin is normally used for plant regeneration, but auxins are not so important as cytokinins for regeneration (van der Valk *et al.* 1992; Wang and Debergh 1995). Shoot tip explants of onion are the best source for callus formation and plantlet regeneration (Khar *et al.* 2005).

For the induction of gynogenesis, the ideal sucrose concentration was 10% (w/v) (Jain *et al.* 1996).

For obtaining transgenic plants of three varieties of 'Valenciana' onion, Torrentina, Cobriza INTA and Grano de Oro cultivated in Argentina, starting from calli induced from mature zygotic embryos, using two strains of *Agrobacterium tumefaciens* as transfection vectors. After three to four months an average of 57.4% success for the three varieties was reached. At the end of the first subculture on regeneration medium, 54 calli were considered potentially organogenic because of the green areas observed. At the end of the whole regeneration period, just one normal plant was obtained, that was PCR-negative using specific primers for *uid*A and *npt*II (Krishnapura 2005).

Generally onion plants are sensitive to weeds but the transfer of a resistance gene against herbicides would lead to simple control of weeds. Eady (2007) reported how only onion plants, which had a resistance gene (*bar*) against glyphosate (a general herbicide), remained intact after spraying, while all weeds died except for a few clovers that were severely stunted. The transgenic onions were not affected by the treatment. Control non-transgenic plots were either sprayed as for the transgenic lines, hand-weeded, or received no weed control.

Some beneficial genes of onion plants were identified and utilized for estimation of their sensitivity potential against feeding nymphs of mustard aphid (*Lipaphis erysimi* (Kaltenbach)), a major sap-sucking insect pest of Indian mustard (*Brassica juncea* (L.) Czern.), an oilseed crop. These genes were capable of offering a defense against sap-sucking insects either by adversely affecting the survival of the insects, or by affecting their fecundity and/or the ability to transmit pathogens (Munshi *et al.* 2006).

The responses of six Iranian onion genotypes to *in vitro* gynogenesis showed significant variations between two media (JAF (MS medium, glucose, and TB) and F6 (BDS medium, sucrose, BA, 2,4-D) in terms of embryo rate, percentage of callus formation and percentage of hyperhydrated flowers. A high correlation between media and cultivars was also shown. F6 medium produced more embryos, hyperhydrated flowers and callus than JAF (Hassandokht *et al.* 2000). Other results showed an inhibitory effect of cold on haploid formation and of the induction of a high frequency of diploid ovule-derived plants in one factorial combination. Concerning the production of haploid plants, an analysis of variance of the data showed significant differences (P=0.05) between the two media used and a high interaction (P=0.05) between media and cultivars. The most responsive Iranian onion was 'Gholigheseh-e-Zanjan' (0.56% of gynogenic embryos); the least responsive was 'Sefid-e-Kamare-e-Khomain' (0.07%). The induction of diploid ovule-derived plants at a high frequency, never before obtained in onion gynogenesis, was achieved in 'Ghermez-e-Azarshahr' when flowers were cultured on new medium and incubated at 17°C during the first 40 days of culture. The diploid/haploid ratio found in this factorial combination was 36/1 while that usually observed in a process of onion gynogenesis ranges between 1/8 and 1/9. The RAPD profiles obtained with four polymorphic primers from the DNA analysis of 23 R_0 plants, chosen at random among the 73 diploids obtained showed that 22 of them were homomorphic. Within the donor plant population, the RAPD profiles were found to be polymorphic. These results support the hypothesis of the occurrence of apomictic-like events at the base of the induction of these diploid plants since all the embryos were of ovule origin (Hassandokht and Campion 2002).

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