*Middle Eastern and Russian Journal of Plant Science and Biotechnology* ©2009 Global Science Books

# Effect of Onion Set Size and Cultivar on Production of Green Bunch Onion (*Allium cepa*)

**Naser Alemzadeh Ansari[1*] • Jaime A. Teixeira da Silva[2] • Najmeh Yazdani[1]**

[1] Department of Horticulture, Faculty of Agriculture, Shahid Chamran University, Ahwaz, Iran
[2] Department of Horticultural Science, Faculty of Agriculture, Kagawa University, Miki-cho, Ikenobe, Kagawa-ken, 761-0795, Japan

*Corresponding author*: * ansari_n@scu.ac.ir

## ABSTRACT

At the end of winter and early spring in Iran, when there are fewer bulbs, green onion (*Allium cepa*) can be a suitable substitute for onion bulb. In order to determine the effect of bulb size (diameter) and cultivar on growth and yield of green onion, an experiment was conducted in 2005-2006 using three cultivars: 'Ramhormozi', 'Behbahani' and 'Primavera'. Two size sets based on initial bulb diameter were used: small (< 1.5 cm in diameter) and large (diameter = 1.5-2.5 cm). A number of criteria were measured at harvest, following the growth of these different sized bulbs, several of which showed significant differences. Particularly noticeable was the enhanced production of vegetative and reproductive organs in plants derived from larger bulbs. 'Ramhormozi' and 'Behbahani' showed the highest and lowest yield, respectively while 'Ramhormozi' and 'Primavera' had the longest and shortest bolt stems, respectively. 'Ramhormozi' is thus most suitable as a green onion while 'Primavera' is ideal for bulb production.

**Keywords:** bulb, local, cultivar resistant, scape

## INTRODUCTION

Onions are one of the main vegetable crops in the world. They have high mineral and organic contents essential for human health (Raj and Yadav 2005). Therefore, onion is a commonly used ingredient in recipes. As the world's population increases, so too has onion production increased, and according to FAO statistics, total onion production in the world reached 54,762 Kt in 2004. In mountainous and high-altitude regions of Iran, which have a cold climate, sowing date and crop harvest are in spring and at the end of summer, respectively. However, in the southern provinces of Iran where many plains occur (Persian Gulf side and Amen seaside, and the plains area) the sowing date is from the end of summer to the middle of autumn and the harvesting date is from the middle of spring to the beginning of summer (Alemzadeh Ansari 2007b). Occasionally, in late March, there is a lack of onion bulbs in Iranian markets caused by a short shelf life and lack of optimal storage conditions. In this period, to compensate, green bunch onions are frequently used. Onion set, i.e. a small bulb, should be used for early production of green or bulb onions because early stages of growth and development of onion seedling are very slow and require considerable time. So in some countries such as Bangladesh as much as 30% of the bulb crop is produced by onion set (Rabinowith and Currah 2002).

Of common knowledge, genetic and environment factors, and the interaction between them affect onion growth and development. Temperature and photoperiod and the interaction between them can be measured from main environmental factors in one region, where they affect the growth and development of an onion set (Khokhar 2008a). Temperature also affects all onion production stages, especially germination, growth and development of leaves, and the production of bulbs or scapes. Growth and development of cultivars are different at low and high temperatures. Onion cultivars produce a scape at a relative low temperature range (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 (Alemzadeh Ansari 2007b). For example, plants produced from sets which are stored at 30°C produce less bolt stems in contrast to sets stored at 10°C (Khokhar *et al*. 2007). The reaction of Iranian cultivars to photoperiod differs (Tarakanov and Alemzadeh Ansari 1997). Bulb production occurs in long photoperiods, but early cultivars react faster to a long photoperiod. The interaction between temperature and photoperiod strongly affects bulb production or the flowering stalk. The bulbing ratio increases proportionally with increasing temperature and photoperiod. Increasing photoperiod promoted bulbing, while under very short photoperiods (8 h $d^{-1}$) no cultivars bulbed, even after 60 d of growth (Tarakanov and Alemzadeh Ansari 1997). The time to bulb maturity decreased linearly with increasing temperature and lengthening photoperiod. Under low temperatures, the time to floral initiation shortened as the photoperiod increased (8–14 h $d^{-1}$) (Khokhar 2008a). The diameter of the set is the primary factor that affects bulb or flower stalk production. A large onion set produces flowering stalks more rapidly then a small one (Heath and Mathur 1944). Yamaguchi (1980) reported that the ideal size of a set should be 1.5-2.0 cm in diameter. Bulbs greater than 2.5 cm in diameter become vernalized at low temperature and are prone to bolting. Onion seedlings are typically vernalized after the juvenile stage (Brewster 1997). A small onion set requires more time to complete early growth (juvenile) stages. At the beginning of the cold season, because the juvenile stage has not yet been completed, small onion sets can not vernalize, or perhaps, after vernalization following an increase in temperature, they devernalize and can not initiate a scape. Consequently the appearance of bolting plants will decrease and as temperature increases and photoperiod lengthens in spring the production of bulbs increases.

Onion cultivars can be classified according to their market use (green, fresh, or dehydrated bulbs). Different cultivars have various sensibilities to bolting (Holdsworth 1944). A combination of factors, including variety, plant, temperature, duration of temperature, and timing of temperature

Received: 8 April, 2009. Accepted: 27 June, 2009.

Original Research Paper

**Table 1** Mean squares of cultivar and set size and interaction on growth and development criteria of onion.

| Sources of changes | df | Plant height (cm) | Leaf № | Leaf length (cm) | Scape length (cm) | Double bulbs (%) | Bulb diameter (cm) | Neck diameter (cm) | Bulbing index | Bulb fresh weight (g) | Leaf fresh weight (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cultivar | 2 | 106.2$^{n.s.}$ | 133.0* | 213.8** | 2094.8** | 2.4* | 5.1$^{n.s.}$ | 9.4** | 1.4** | 1020.1$^{n.s.}$ | 1472.2$^{n.s.}$ |
| Set size | 1 | 551.0** | 165.4* | 44.0$^{n.s.}$ | 1926.0* | 5.0** | 6.5$^{n.s.}$ | 6.9* | 0.0$^{n.s.}$ | 8750.5$^{n.s.}$ | 2745.2$^{n.s.}$ |
| Interaction | 2 | 177.0$^{n.s.}$ | 49.9$^{n.s.}$ | 135.0** | 1782.0** | 1.5$^{n.s.}$ | 2.4$^{n.s.}$ | 5.6* | 0.5$^{n.s.}$ | 1678.6$^{n.s.}$ | 3192.1$^{n.s.}$ |
| Error | 15 | 62.1 | 31.2 | 31.4 | 254.4 | 0.6 | 3.7 | 1.2 | 0.2 | 1310.5 | 1097.0 |

* Significant at $P < 0.05$, ** Significant at $P < 0.01$, $^{n.s.}$ Not significant.

all interact to determine whether and when bolting occurs (Voss and Maybress 1998). Cultivars that are first able to produce a flowering stalk will then be suitable for green onion production.

The aim of this study was to assess whether green onions could be produced based on the initial size (i.e. diameter) of the set. Although the growth conditions and cultivars are cultivated in southern areas of Iran the principle could be more broadly applied to similar growing conditions around the world and extended to other cultivars.

## MATERIALS AND METHODS

The investigation was conducted during the growing season (20 November 2005 to 20 March 2006) at the experimental field of the Agricultural Faculty, Shahid Chamran University of Ahwaz (31°19′ N and 48°40′ E, elevation 12 m asl), Iran. The experimental design was a spilt plot in randomized complete blocks with 3 replications. The main plots included two bulb diameter sizes (> 1.5 and 1.5 to 2.5 cm) and sub-plots were three onion cultivars [local cultivars (‘Ramhormozi’ and ‘Behbahani’), and an improved cultivar (‘Primavera’, from the USA)]. The onion sets used were produced in spring 2006 and stored for 120 days at 12-15°C in summer 2006. Then, in order to adapt to field conditions and decrease the effects of cold storage, they were transferred to the field 20 days before sowing. The area of each treatment was 2 $m^2$, and each replication had 5 lines. Onion sets were planted in a field at an inter-row spacing of 40 cm and an inter-plant distance of 8 cm. At all stages and in all treatments, the same agronomic practices, namely irrigation (12 times), fertilizer application (150 kg N, 100 $P_2O_5$), and herbicide treatments (Oxyfluorfen 1.5 l $ha^{-1}$), were carried out. At harvesting time, sampling of plants was carried out in the morning and several plant characteristics, including plant length, leaf number, flowering stalk height, leaf area, diameter of bulb and neck, fresh and dry weights of bulb and leaves were measured, while the bulbing index was calculated by dividing the bulb diameter by the neck diameter. Statistical analysis of experimental data was conducted with the MSTATC software package and the means were separated by Duncan’s multiple range following ANOVA ($p<0.05$).

## RESULTS

The changes of temperature from 20 November 2005 to 20 March 2006 are shown from set sprouting up to harvesting date (**Fig. 1**). Minimum, average, and maximum temperatures were 21.2, 15.9, and 10°C, respectively. During the experimental period, maximum temperature was optimum for growth and development of onion. Our study shows that even though there was a considerable difference between the average and minimum temperatures, onion plants were not influenced by cold temperature at the sowing date although it is reasonable to expect that vernalization of onion plants was very high because the temperature range for vernalization is 1 to 17°C while the optimum range is 9-12°C (Brewster 1997).

At harvesting time, the effect of cultivar on leaf number and length, length of scape, bulbing index, and diameter neck was significant (p=0.05), but the effect on plant height, leaf area, bulb diameter, and bulb and leaf fresh weight was not (**Table 1**).

The effect of set size on plant height, double bulbs, scape length, fresh and dry weights of bulbs was significant, but the effect on leaf number, length, and area, diameter of the bulb and neck, and fresh weight of leaves was not (**Table 1**).

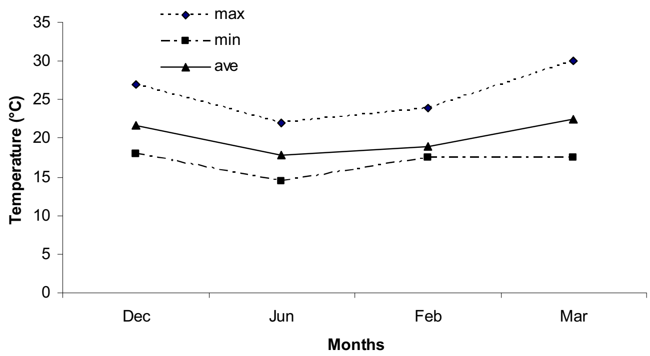


**Fig. 1 Changes in temperature from sprouting set to harvesting date.**

The interaction effect between cultivars and set size on leaf length, scape length, bulb diameter, and fresh weight of leaves was significant, but the effect with other measured characters was not (**Table 1**).

## Plant height

The large set produced taller plants than the small set (**Table 2**). The interaction effect between cultivar and set size was clear in ‘Bahbahani’, which produced tallest and shortest plants with large and small sets, respectively (**Table 3**). After passing the juvenile stage, cold conditions during late autumn and winter cause the onion plant to vernalize. In doing so, the pseudo stem length and plant height increase while leaves are more rapidly produced. These shifts can arise from changes in hormone balance. For example, exogenously-applied $GA_3$ in tomato plants caused an increase in plant height (Khan *et al*. 2006). Dry plant weight, plant age, cultivar and cold period were considered to be the main factors for effective vernalization in ‘Ghermaz Azarshahar’ and ‘Pusa Red’ (Alemzadeh Ansari and Tarakanow 2000).

## Leaf number

Maximum and minimum leaf numbers were observed in ‘Bahbahani’ and ‘Primavera’, respectively. Moreover, the large set produced more leaves than the small set (**Table 2**). The interaction effect between cultivar and set size indicated that most and fewest leaves formed in ‘Ramhormozi’ and ‘Primavera’, respectively with the large sets (**Table 3**). ‘Primavera’ is an early regional cultivar that reacts to environmental factors very rapidly (Alemzadeh Ansari 2007d). In the first month of growth, plants produced from the large set had more leaves and were longer then those derived from the small set. Consequently, these plants reacted early to changes in photoperiod and temperature.

## Leaf length

Longest and shortest leaves were observed in ‘Primavera’ and ‘Ramhormozi’, respectively (**Table 2**). The interaction effect between cultivar and set size indicated that the longest and shortest leaves were in ‘Primavera’ and Bahbahani, respectively when the small set was used (**Table 3**). This result is similar to that reported by Khokhar (2007b), who

**Table 2** Mean effects of cultivar and set size on growth and development criteria of onion.

| Cultivar | Plant height (cm) | Leaf № | Leaf length (cm) | Scape Length (cm) | Double bulbs (%) | Bulb diameter (cm) | Neck diameter (cm) | Bulbing index | Bulb fresh weight (g) | Leaf fresh weight (g) |
|---|---|---|---|---|---|---|---|---|---|---|
| Ramhormozi | 60.8 a* | 15.3 a | 45.8 b | 26.2 a | 48 a | 4.7 a | 3.6 a | 1.47 b | 79.7 a | 69.2 a |
| Behbahani | 65.0 a | 15.4 a | 47.1 b | 29.6 a | 50 a | 5.5 a | 3.9 a | 1.41 b | 81.1 a | 85.8 a |
| Primavera set size | 68.0 a | 8.3 b | 55.3 a | 0.0 b | 0 b | 3.9 a | 1.9 b | 2.16 a | 60.9 a | 58.9 a |
| Large | 69.4 a | 15.6 a | 50.8 a | 27.5 a | 53 a | 5.2 a | 3.7 a | 1.69 a | 93.0 a | 82.0 a |
| Small | 59.8 b | 10.3 b | 48.0 a | 9.6 b | 30 b | 4.2 a | 2.6 a | 1.60 a | 54.8 b | 60.6 a |
| Total | 64.6 | 13.0 | 49.4 | 18.6 | 40 | 4.7 | 3.1 | 1.68 | 73.9 | 71.3 |

Different letters within a column indicate significant differences by Duncan's Multiple Range Test, $P$=0.05.

**Table 3** Interaction effects between cultivar and set size on growth and development criteria of onion.

| Cultivar | Set size | Plant height (cm) | Leaf № | Leaf length (cm) | Scape length (cm) | Doubled bulbs (%) | Bulb diameter (cm) | Neck diameter (cm) | Bulbing index | Fresh weight bulb (g) | Fresh weight leaf (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ramhormozi | Large | 67.1 ab* | 19.5 a | 47.5 ab | 52.4 a | 70.0 a | 5.7 a | 5.0 a | 1.23 b | 111.8 a | 85.7 ab |
| | Small | 54.4 b | 11.0 ab | 44.0 ab | 0.0 b | 0.0 b | 3.7 a | 2.2 b | 1.70 b | 47.7 b | 52.7 b |
| Behbahani | Large | 73.5 a | 19.3 a | 52.4 ab | 30.3 a | 63.0 a | 6.1 a | 4.4 ab | 1.44 b | 102.9 ab | 112.9 a |
| | Small | 56.5 b | 11.5 b | 41.9 c | 28.9 a | 38.0 a | 4.8 a | 3.4 b | 1.38 b | 59.3 ab | 58.7 ab |
| Primavera | Large | 67.5 ab | 8.0 b | 52.4 ab | 0.0 b | 0.0 b | 3.8 a | 1.6 b | 2.41 a | 64.4 ab | 47.4 b |
| | Small | 68.5 ab | 8.5 ab | 58.3 a | 0.0 b | 0.0 b | 3.9 a | 2.2 b | 1.91 a | 57.4 ab | 70.5 ab |

Different letters within a column indicate significant differences by Duncan's Multiple Range Test, $P$ = 0.05.

showed that leaf length between 'Stuttgarter' and 'Sturon' was significantly different when onion set of cultivars were grown.

## Scape length

Tallest and shortest scapes were observed in 'Babahni' and 'Primavera', respectively. The large set produced taller scapes than the small set (**Table 2**). The interaction effect between cultivar and set size indicated that tallest and shortest scapes formed in 'Bahbahani' with the large set and in 'Primavera' with the small set, respectively (**Table 3**). Variations in scape length between different cultivars indicated that each cultivar had a different scape initiation date. Local cultivars vernalized in 60 days and produced scapes (**Fig. 2**) while 'Primavera' was resistant to bolting, especially in the small set.

The production of scapes within a single cultivar, i.e. 'Primavera', varied considerably, especially from the large set (**Fig. 3**). In other words, as set diameter increased, so too did scape number (**Fig. 2**). This result supports that by Khokhar (2008b), who showed that small sets bolted little or not at all, while the bolting percentage increased linearly with increasing set size, following a linear relationship. In our results, however, the 'Primavera' small set did not bolt while that of 'Bahbahani' did, i.e. the small onion set showed a different response to cold depending on the cultivar.

## Percentage double bulbs

Local cultivars produced double or multiple bulbs, especially in the large set, while the improved cultivar produced single or small double bulbs. The large set (when all cultivars were pooled) produced more double bulbs than the small set (**Table 2**). The interaction effect between cultivar and set size indicated that the maximum and minimum percentage of double bulbs were recorded in 'Bahbahani' with a large set and in 'Primavera' with a small set, respectively (**Table 3**). Matimati *et al.* (2006) also showed that large sets produced triple, unmarketable bulbs with a weight comparable with small sets. In their study, too, cultivar and set size interacted to determine the marketable bulb number and weight. Many Iranian onion cultivars (e.g. 'Behbahani', 'Ramhormozi', 'Ghermaz Azarshahar') have multiple centers, but in first year, they produce bulbs with a similar single center, 5 to 7 of which form double bulbs, but as temperature and light intensity increase, the percentage of double bulbs increases.


**Fig. 2 Green onion production by small (left) and large (right) sets in 'Bahnahani'.**

## Neck diameter

Local cultivars produced thicker necks than the improved cultivar (**Table 2**). The interaction effect between cultivar and set size indicated that the thickest and thinnest necks formed in 'Ramhormozi' and 'Primavera', respectively with a large set (**Table 3**).

When onion plants enter the dormancy phase, neck diameter begins to decrease as a mechanism to prevent the entry of pathogens into the plant (Alemzadeh Ansari 2007c). Local cultivars vernalized very soon and if they were not


**Fig. 3 Onion bulb production using small (left) and large (right) sets in 'Primavera'.**

harvested for green bunch onion, then they would grow and develop to produce seed, and thus had thick necks (data not shown, but visible in **Figs. 2** and **3**). A similar phenomenon occurred when onion set was planted early. Madisa (1994) showed that February planting produced 24% bolting plants, March planting only resulted in 7% while April planting gave no bolters. However, plants originating from the big set in 'Primavera' had a double reaction to cold: in the first group, they began to form bulbs early and the diameter of the neck started to decrease, while in the second group, they produced scapes (**Fig. 3**).

## Bulbing index

The bulbing index is the ratio of the largest bulb diameter to its neck diameter, and when this ratio reaches 2, bulb formation begins (Mondal *et al*. 1986). Highest and lowest bulbing index was observed in 'Primavera' and 'Bahbahani', respectively (**Table 2**). The interaction effect between cultivar and set size indicated that highest and lowest bulbing index occurred in 'Primavera' and 'Ramhormozi', respectively with a large set (**Table 3**). In other words, local cultivars could not produce bulbs by set while the improved cultivar could. This is because plants produced from the local cultivar by set have almost no requirement for cold to vernalize, and soon bolt.

## Fresh bulb weight

The large set produced heavier bulbs than the small set (**Table 2**). The interaction effect between cultivar and set size indicated that maximum and minimum bulb fresh weight was recorded in 'Ramhormozi' with a large and small set, respectively (**Table 3**). In local cultivars ('Ramhormozi' and 'Behbahani'), bulbs enlarged giving rise to axillary bud growth, and produced double or multiple bulbs (Rabinowith 1979) if they did not produce a scape.

## Leaf fresh weight

The interaction effect between cultivar and set size indicated that 'Bahbahany' and 'Primavera' had highest and lowest leaf fresh weights, respectively in the large set (**Table 2**).

# DISCUSSION

Local cultivars ('Ramhormozi' and 'Bahbahani') produced bulbs when they were propagated by seeds or after transplanting (Alemzadeh Ansari 2007c), and they had a long shelf life (Alemzadeh Ansari 2007a). Previously, bulbs were produced directly by seed or transplanting within 180-240 days, but the duration depended on the cultivar (Alemzadeh Ansari 2007c) while in this experiment it was 120 days (**Fig. 4**). This result is supported by the findings of Munoz et al. (1995) who showed that small bulbs could successfully produce marketable onions. Small 'Primavera' bulbs, when used as planting stock, successful result in an early bulb onion harvest but with increasing set size, the number of bolting plants increased. Khokhar *et al.* (2007b) showed that plants of two onion cultivars 'Sturon' and 'Stuttgarter', flower induction and further development of the inflorescence depended on low temperature and also on a longer cold-storage period. Inflorescence emergence and subsequent development (spathe and floret opening) occurred earlier with increasing exposure to low temperature, so that a one-day increase in chilling duration equalled 0.16- and 0.19-day reductions in spathe opening in 'Hygro' and 'Delta', respectively. Currah and Proctor (1990) showed that, depending on the cultivar, optimum chilling duration ranged from 7 to 90 days at 3–11.8°C for floral initiation. In


**Fig. 4 Transplant produced by seed (left) and seedling produced by set (right) in 'Primavera' at the field research station of Shahid Chamran University, Ahwaz, Iran.**

**Table 4** Effects of two methods of production of onion seedling in Ahwaz conditions from sets or seeds in 75 days on some morphological characters.

| Cultivar | Produced seedling by seeds | | | Produced seedling by sets | | |
|---|---|---|---|---|---|---|
| | **Leaf fresh weight (g)** | **Bulb fresh weight (g)** | **№ leaves** | **Leaf fresh weight (g)** | **Bulb fresh weight (g)** | **№ leaves** |
| Primavera | 3.14 | 1.13 | 4.2 | 18 | 17 | 9.1 |
| Behbahani | 1.17 | 0.44 | 3.7 | 17 | 18 | 7.1 |
| Ramhormozi | 1.14 | 0.44 | 3.7 | 24 | 27 | 10.1 |


**Fig. 5 Segregation in harvesting time of 'Primavera' onion bulbs when propagated by set at the field research station of Shahid Chamran University, Ahwaz, Iran.**

'Bawku' from West Africa, however, optimal induction occurred at 15-21°C, whereas cultivars from northern Russia had an optimum of 3-4°C (Brewster 1994). However, in this experiment when seedlings were produced by sets at early growth stages their growth and development was rapid compared with seedlings derived from seed direct (**Table 4**). Early and rapid growth of plants produced by set resulted in bigger seedlings to be produced, which can vernalize upon exposure to cold in late autumn and early winter. 'Bahbahani' and 'Primavera' were least and most resistant to bolting, respectively. 45 days after planting, plants that were sensitive to bolting produced a scape. Local cultivars vernalized faster and produced multiple stem stalks, but in 'Primavera' only the single stem stalk and axillary buds produced bulbs (**Fig. 3**). In addition, vernalization responses of onion plants depended on the set size. Plants produced from larger sets vernalized faster in appropriate temperature, nutrient, and light intensity conditions compared to the smaller set, but scape apparent depends on the cultivar. These results are supported by those of Brewster (1994) in which large bulbs rather than small bulbs complete thermal and competition phases of inflorescence development.

In Iran, as in many countries, production of seed by the "seed-to-bulb-to-seed" method was completed within two years; 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. Therefore, one improvement cycle for cultivars needs 2 years (Alemzadeh Ansari 2007b). Rapid seedling growth form sets caused some developmental stages to be completed more quickly in the first year and hence the probability of producing green bunch onion or seeds, or screening of sensitive plants to bolt (**Fig. 5**). In addition, bulbs which are resistant to bolting can be selected for cultivar improvement programs within in one year.

## ACKNOWLEDGEMENTS

We thank the Dean of Research, Shahid Chamran University and the Dean of the Faculty of Agriculture, for facilities used in this project.

## REFERENCES

**Alemzadeh Ansari N** (1997) Ecological characters formation yield onion in low latitudes. PhD Thesis, Vegetable Growing Department, Moscow University, 129 pp

**Alemzadeh Ansari N, Tarakanow IK** (2000) Effects of temperature in the period before vernalization of the growth and development of three onion cultivars (*Allium cepa*). *The Scientific Journal Agriculture* **23**, 25-39

**Alemzadeh Ansari N** (2007a) Effect of cultivars on storage losses in onion under hot conditions. *Journal of Applied Horticulture* **9**, 37-40

**Alemzadeh Ansari N** (2007b) Onion cultivation and production in Iran. *Middle Eastern and Russian Journal of Plant Science and Biotechnology* **1**, 26-38

**Alemzadeh Ansari N** (2007c) Reaction of some southern Iranian onion ecotypes to translocation. *Middle Eastern and Russian Journal of Plant Science and Biotechnology* **1**, 20-25

**Alemzadeh Ansari N** (2007d) Effect of density, cultivars, and sowing date on onion sets production. *Asian Journal of Plant Sciences* **6**, 1147-1150

**Brewster JL** (1994) *Onions and Other Vegetable Allium*, CAB International, Wallingford, UK, 236 pp

**Brewster JL** (1997) Onions and garlic. In: Wien HC (Ed) *The Physiology of Vegetable Crops*, CAB International, Wallingford, UK, pp 581-619

**Currah L, Proctor FJ** (1990) *Onions in Tropical Regions*, Bulletin 35, Natural Resources Institute, Chatham, UK, 202 pp

**Heath OVS, Mathur PB** (1944) Studies in the physiology of the onion plant: II. Inflorescence initiation and development, and other changes in the internal morphology of onion sets, as influenced by temperature and day length. *Annals of Applied Biology* **31**, 173-186

**Holdsworth M** (1944) A comparative study of onion varieties in relation to bolting and yield when grown from sets. *Annals of Applied Biology* **32**, 22-34

**Khokhar KM** (2008a) Effect of temperature and photoperiod on the incidence of bulbing and bolting in seedlings of onion cultivars of diverse origin. *The Journal of Horticultural Science and Biotechnology* **83**, 488-496

**Khokhar KM** (2008b) Effect of set-size and planting time on the incidence of bolting, bulbing, and seed yield in two onion cultivars. *The Journal of Horticultural Science and Biotechnology* **83**, 481-487

**Khokhar KM, Hadley P, Pearson S** (2007a) Effect of photoperiod and temperature on inflorescence appearance and subsequent development towards flowering in onion raised from sets. *Scientia Horticulturae* **112**, 9-15

**Khokhar KM, Hadley P, Pearson S** (2007b) Effect of cold temperature durations of onion sets in store on the incidence of bolting, bulbing and seed yield. *Scientia Horticulturae* **112**, 16-22

**Khan MA, Gautam C, Mohammad F, Siddiqui MH, Naeem M, Khan MN** (2006) Effect of gibberellic acid spray on performance of tomato. *Turkish Journal of Biology* **30**, 11-16

**Madisa ME** (1994) The effect of planting date, set size, and spacing on the yield of onion (*Allium cepa*) in Botswana. *Acta Horticulturae (ISHS)* **358**, 353-358

**Matimati I, Murungu FS, Handiseni M, Dube ZP** (2006) Effect of set size and cultivar on marketable yield of onion (*Allium cepa*). *Journal of New Seeds* **8 (1)**, 61-70

**Mondal MF, Brewster JL, Morris GEL, Butler HA** (1986) Bulb development in onion (*Allium cepa* L.). I. Effect of plant density and sowing date in field conditions. *Annals of Botany* **58**, 187-192

**Muñoz SO, Gonzalez DF, Lewis A** (1995) Effect of two propagate size on the early production of three onion (*Allium cepa* L.) cultivars. *Proceedings of the International Society of Tropical Horticulture* **39**, 16-22

**Rabinowith HD** (1979) Doubling of onion bulbs as affected by size and planting date of sets. *Annals of Applied Biology* **93**, 63-66

**Rabinowith HD, Currah L** (2002) *Allium* Crop Science, CABI, Wallingford, UK, 544 pp

**Raj N, Yadav DS** (2005) *Advances in Vegetable Production*, New Delhi Research Co. Book Centre, 995 pp

**Ruggeri A, Branca F** (1994) Sowing date and $GA_3$ in onion seed production. *Acta Horticulturae (ISHS)* **362**, 35-42

**Tarakanov IG, Alemzadeh Ansari N** (1997) Photoperiodic response in popular onion varieties grown in Iran. *Journal of Isvestia, TCXA* **1**, 83-90

**Voss R, Maybress KS** (1998) Green onion production in California. University of California, division of Agriculture and Natural Resources, Publication 7243, 3 pp

**Yamaguchi M** (1980) *World Vegetables, Principles, Productions and Nutritive Values*, University of California, Davis, California, pp 187-188