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# Evaluation of short day onion (*Allium cepa* L.) genotypes for quantity and quality traits

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**ABSTRACT**

**Purpose:** In the first stage to produce open pollinated and hybrid onion cultivars, identification of compatible genotypes as breeding base populations with the climatic conditions is of special importance**.** Thus, this research was performed to evaluate short day onion hybrids and achieve a breeding base population by identifying the best genotypes in terms of quantity and quality traits and also for studying the reaction of genotypes to the climatic conditions of Isfahan and Khuzestan. **Research method: F**ifteen onion genotypes were evaluated as complete block design with three replications in two locations (Isfahan and Khuzestan) under field condition during the 2017-2018 growing season. The traits evaluated included: bulb yield, average bulb weight, dry matter content, total soluble solids, and weight loss. **Findings:** According to the results of Isfahan location, Savannah Sweet and Saba hybrids had the highest bulb yield (42.72 t/ha and 41.05 t/ha, respectively) and Vania hybrid with high significant different ($p< 0.05$) was showed the lowest bulb yield (19.77 t/ha). In Khuzestan location, SV6326, Saba and Savannah Sweet for bulb yield (92.38, 89.71 and 89.14 t/ha, respectively) were recognized as super hybrids, in contrast, hybrids: Early Super Select, Behbahan improved population, Super Perfect, Sahar and Vania, were considered as weak hybrids (bulb yields<60 t/ha). In terms of quality traits, Behbahan improved population with 18.84% and 14.75% of total soluble solids as well as 19.52% and 15.77% of dry matter content in Isfahan and Khuzestan locations had significant difference from the other hybrids. Saba hybrid was identified as high bulb yield with low weight loss hybrid, Vania hybrid recognized as low bulb yield and the Savannah Sweet was identified as high yield with high weight loss in two experiments. **Research limitations:** Further work could be done with other commercial short day onion hybrids. **Originality/Value:** These genotypes can be used as parental material in the quantity and quality improvement of bulb onion. In future breeding programmes, emphasis should be given to Saba hybrid for producing high bulb yield and best quality onion variety.

## INTRODUCTION

The Onion (*Allium cepa* L.) with chromosome number of 2n = (2x) =16 is also called bulb onion. Onion is one of the most important vegetable and spice crop grown intemperate, sub-tropical and tropical climate throughout the world (Upadhyay et al., 2020). Onion is one of the most important vegetables of Iran that have been cultivated for many years ago. Due to particular diversity that onions show in the eastern Mediterranean countries such as regions of Pakistan, Uzbekistan, Tajikistan, Afghanistan and northern Iran, it is thought to origin from these areas (Brewster, 2008). The level of onion harvest in Iran in the growing year 2019-2020 was about 67000 hectares and yield was about 49 t/ha. The highest yield of onions in the country is belonging to Isfahan with about 66 t/ha (Ahmadi et al., 2021).

Despite its special importance worldwide of this product, it has not made significant genetic progress compared to other vegetable crops (McCallum et al., 2008). One of the causes can be due to the lack of proper evaluation and data classification (Bal et al., 2020a). Genetic improvement in any breeding program requires quantifying the genetic diversity exists within and between the germplasm to identify parents with the maximum genetic diversity for realizing higher heterosis and obtaining superior recombinants. In addition, by achieving genetic distance through the study of genetic diversity, the probability of achieving transgressive segregants in the generations increases (Raj et al., 2022). The results of study performed on 12 short-day onion cultivars showed that Cyrus hybrid and Texas Yello Grano 502 cultivar with high bulb yield, stayed in the first rank. Also, the solids soluble total (SST) in Texas Yello Grano 502 cultivar was significantly lower than Cyrus (Aminpour et al., 2011). In a comparison among the onion Behbahan improved population, the source population (local Behbahan population) and Primavera cultivar for marketable yield, Primavara variety and Behbahan improved population of showed significantly different ratio to Behbahan local population. But the storability in the Behbahan improved population was significantly higher than Primavera variety (Darabi & Salehi, 2014).

Bulb is a storage organ and therefore it is more suitable for storage than other vegetables. Storage of onion is a multiplex process and due to storage losses, whole quantity of the total production cannot be guaranteed to be consumed by the people (Sharma et al., 2017). At various steps throughout the marketing process from farmer-to-consumer, bulbs can be stored as short or long terms depending on market needs (Petropoulos et al., 2017). Select the appropriate cultivar is the first step to increase storage potential. After that, both Pre and post-harvest factors affect to improve storability consist on: cultivation practices such as irrigation and fertilization, harvest stage, bulb handling, curing and storage conditions. Quality of onion bulbs during storage is being affected mostly due to water losses, sprouting, rooting and changes in chemical composition (Petropoulos et al., 2017).

Genetic improvement of traits and development of varieties with high production potential is the main goals of plant breeding programs. Onion is an outcross plant that in the first stage to produce hybrid seeds requires a breeding base population with desirable traits to be able to identify the worthy parental lines within. Identification of compatible genotypes with the climatic conditions is of special importance. In order to determine the most compatible genotypes, the study of selected genotypes in field experiments in terms of quantity and quality traits is necessary. According to these explanations, the genetic materials used in this study included the hybrids have recently been introduced to the Seed and Plant Certification and Registration Institute and subjected to distinctness, uniformity and stability (DUS) test. Therefore, this project was implemented with the following objectives: 1) Achieving a breeding base population by identifying the best genotypes in terms of quantity

and quality traits, 2) Study of the reaction of genotypes to the climatic conditions of Isfahan and Khuzestan.

## MATERIAL AND METHODS

### Plant material

The genetic materials of this project include 11 commercial short onion hybrids named Sahar, Super Perfect, Paliz, Saba, Vania, Early Super Select, Savannah Sweet, Golden eye, Duster, Hybrid 6326, Imperatriz and Behbahan onion improved population along with Primavera, Cyrus and Texas Early Grano as controls introduced from different companies. The characteristics of hybrids consist of: yellow skin color, single, single center, medium dry matter (except Super Perfect, which has high dry matter content), and low or very low bolting rate and moderate neck diameter (Table 1).

### Field evaluation

Fifteen onion genotypes (Table 1) were grown as seedling in two environments at Isfahan Agricultural and Natural Resources Research and Training Center (Kabutarabad Agricultural Research Location, 25 km east of Isfahan, 51˚ 51´E and 30˚ 31´N, 1545m altitude) and Khuzestan Agricultural and Natural Resources Research and Training Center (Behbahan Agricultural Research Location, 30˚36´ N and 51˚51´E, 320 m altitude) field conditions during the 2017-2018 growing season. The results of soil and water tests are given in table 2 and 3, respectively.

For each experiment, a complete block design with three replications was used. Each plot contained four 4m long rows with spaced 0.3 m between rows and 0.1 m inside the row. Usual cultural practices were followed for seedling-bed preparation, transferring, irrigation and control of weed and pests. Cultivation was done by transplanting in two experiments. In Khuzestan, the seedlings were transferred to the main land after two- to-three leaf stage in late December. In the Isfahan experiment, due to the winter cold and the risk of spring, the seedlings were transferred to the main land in early March. The bulbs were harvested on 14 May and 17 July in Khuzestan and Isfahan, respectively.

**Table 1.** The name and characteristics of onion genotypes were used in study

| No. | Hybrid name | Importer company | Breeder | Characteristics |
|---|---|---|---|---|
| 1 | Sahar | Golsam Gorgan | HuizerZaden | |
| 2 | Super Perfect | Abadgaran | ECO SEEDS | |
| 3 | Paliz | Hezare-sewom | FINE SEEDS | |
| 4 | Saba | Golsam Gorgan | HuizerZaden | yellow skin color, single, |
| 5 | Vania | Parskeshavarz | Apollo Seeds | single center, medium dry matter (except Super |
| 6 | Early Super Select | Zarindon-jonoob | Agrotip | Perfect, which has high dry matter content), |
| 7 | Savannah Sweet | Falat | - | low or very low bolting rate and moderate neck |
| 8 | Golden eye | Falat | - | diameter |
| 9 | Duster | Falat | - | |
| 10 | SV6362 | Falat | - | |
| 11 | Amprialize | Falat | - | |
| 12 | Behbahan improved | Khuzestan | Khuzestan | White, high dry matter content |
| 13 | Primavera | Falat | - | White, medium dry matter |
| 14 | Cyrus | Falat | - | White, medium dry matter |
| 15 | Texas Early Grano | Falat | - | Yellow, medium dry matter |

**Table 2.** Results of soil test on Isfahan and Khuzestan location

| Location | Sample (0-30 cm) | EC (dS/m) | pH | Organic C | Available P | Available K | Sand | Silt | Clay |
|---|---|---|---|---|---|---|---|---|---|
| | | | | (mg/kg) | | | % | | |
| Isfahan | Before planting | 5.4 | 7.2 | 0.74 | 30.2 | 350 | 12.6 | 50 | 37.4 |
| | Harvest time | 8.2 | 7.3 | 0.78 | 8.1 | 260 | 12.6 | 46 | 41.4 |
| Khuzestan | Before planting | 2.4 | 7.7 | 0.75 | 3 | 170 | 11.1 | 51 | 37.9 |
| | Harvest time | 2.4 | 7.7 | 0.75 | 3 | 170 | 12.1 | 50 | 37.9 |

**Table 3.** Results of water test on Isfahan and Khuzestan location

| Location | **EC** (dS/m) | pH | $CO_3^{2-}$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{2-}$ | Sum of anions | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | Sum of cations |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | meq/l | | | | | | | | |
| Isfahan | 6 | 7 | 0 | 4.4 | 17.8 | 13.8 | 36 | 19.2 | 18.3 | 17.6 | 36.8 |
| Khuzestan | 1.97 | 7.4 | 0 | 3.2 | 8.8 | 8.0 | - | 8.8 | 3.2 | 8 | - |

**Bulb yield**

Bulb yield for each genotype was calculated per plot. Based on the plot yield bulb, yield bulb per hectare was calculated and expressed in tons per hectare.

**Average bulb weight**

For average bulb weight (g), five randomly selected plants from each treatment and replications were weighed to determine the average weight of bulb.

**Dry matter content**

To calculate the dry matter content of each genotype, 5 bulbs were randomly selected from each plot and their weight was determined. After drying complete samples in the oven (70℃) and fixing weights (about 72 hours), again samples weighted and the dry matter percent was calculated.

**Total soluble solid**

To measure the total soluble solid, 5 bulb samples were randomly selected and after cutting from the second and third layers, the extract was placed on the glass of refractometer (ATAGO, Japan, Brix 0-32 %) and the device number was recorded (Mann & Hoyle, 1945).

**Weight loss**

To measure the storage properties of onion samples, 10 kg of healthy bulbs per hybrid were stored in lattice boxes and maintained under normal conditions for 3 months. Before storage, boxes containing bulbs were weighed. After 3 months, first the bulb sprouting were counted and then the boxes were weighed. In this way, the amount of bulb weight loss of each treatment was accurately determined. During storage, the temperature changes in Khuzestan ranged from 32 to 39.5°C and relative humidity ranged from 27 to 58% and the condition in Isfahan was 15-20°C for temperature and 60-70% for relative humidity. Weight loss (WL) was calculated at the end of the third month using the formula given below (1) (Aske et al., 2017):

$$WL\ (\%) = \frac{P0 - P1}{P0} \times 100 \qquad (1)$$

Where

$P_0$= initial bulbs weight

$P_1$= bulbs weight after 90 days

The means for each trait over three replications were calculated for each hybrid. After Bartlett's test (Arsham, 2010) for homogeneity of variances for two locations, combined analysis of variance was performed using the Proc GLM statement of SAS V-9.0. Also, LSD test was calculated at a probability level of 5% for each trait using SAS software. In order to group the genotypes, in each experiment, cluster analysis was performed on the means data by Ward's method.

## RESULTS

### Combined analysis

Results from the combined analysis showed that the effects of location and variety were significant for all traits (Table 4). Genotype × Location were significant for all measured traits with the exception of weight loss (Table 4). The results showed that for bulb yield, Khuzestan location with 72.69 t/ha had significant different of bulb yield in Isfahan location (29.47 t/ha). But for quality traits: Dry matter content (%) and Total soluble solids (%), Isfahan location showed significant different compared with Khuzestan location. Weight loss in Isfahan location (32.95%) was significantly different of Weight loss in Isfahan location (11.49%). There was significant difference between the two environments for all of the measured traits (Table 5).

### ISFAHAN LOCATION

#### *Mean comparison*

Mean comparison for yield and yield related traits of onion hybrids using LSD test method (5%) showed that Savannah Sweet hybrid (42.72 t/ha) and Saba hybrid (41.5 t/ha) had the highest bulb yield and there is no significant difference with Imperatriz and Golden eye hybrids. Significantly lowest bulb yield was noted in Vania hybrid (19.07 t/ha) (Table 6). In any field trait with different agents, yield is the most important character to be taken under special consideration. Average bulb weight which is directly correlated with yield, the, ranged from 56.18 g to 88.81 g with mean value was obtained 73.97 g. Vania hybrid recorded the highest average bulb weight (88.81 g) whereas smallest bulb size was recorded with SV6362 (56.18 g). Data revealed significant differences for dry matter content. Behbahan improved population registered the maximum value (19.52%) and statistically different from all the other genotypes. Duster hybrid (13.8%) was in the second and, Savannah Sweet, Golden eye, Cyrus and Texas hybrids showed the lowest rank for dry matter content (Table 6). Total soluble solids important quality trait in onion ranged from 8.68% to 18.84%. Behbahan improved population scored highest TSS (18.84%) which was significantly different from other hybrids whereas minimum TSS (8.68%) was recorded with Vania hybrid. There was not significant different among other hybrids. Weight loss, ranged from 21.63% to 50.94%. Among the genotype evaluated, the lowest (21.63%) weight loss was observed in genotype Texas, whereas highest weight loss was recorded with SV 6362 hybrid (50.94%). The results showed that Saba, Sahar and Imperanriz hybrids with low weight loss grouped as superior hybrids (Table 6).

**Table 4.** Combined analysis of variance for quantity and quality traits in studied onion genotypes

| Source of variations | df | Mean of squares | | | | |
|---|---|---|---|---|---|---|
| | | Bulb yield (t/ha) | Average bulb weight (gr) | Dry matter content (%) | Total soluble solids (%) | Weight loss (%) |
| Location | 1 | 42027** | 177275* | 2231.97** | 176.03** | 12243** |
| Error1 (Block in location) | 4 | 597.8 | 3411 | 43.38 | 0.595 | 32.76 |
| Genotype | 14 | 759.4** | 1791** | 13.71** | 22.62** | 172.0* |
| Genotype × Location | 14 | 328.7** | 750.5** | 18.25** | 1.078* | 115.0$^{ns}$ |
| Error 2 (residual) | 56 | 45.7 | 165.8 | 1.99 | 0.517 | 85.04 |
| CV(%) | | 13.23 | 10.88 | 10.9 | 8.214 | 22.83 |
| R- Square | | 0.96 | 0.96 | 0.97 | 0.96 | 0.81 |
| Chi-square value of Bartlett's test | | 453.5 | 384.9 | 711.1 | 695.6 | 489.9 |
| Mean | | 51.08 | 118.3 | 12.94 | 8.76 | 23.15 |

**Table 5.** Mean comparison of quantitative and qualitative traits of short-day onion hybrids for locations and genotypes effects using LSD (0.05) method

| Treatment | Bulb yield (t/ha) | Average bulb weight (gr) | Dry matter content (%) | Total soluble solids (%) | Weight loss (%) |
|---|---|---|---|---|---|
| Location | | | | | |
| Khuzestan | 72.69$^{a}$ | 162.70$^{a}$ | 8.41$^{b}$ | 7.50$^{b}$ | 11.49$^{b}$ |
| Isfahan | 29.47$^{b}$ | 73.97$^{b}$ | 10.63$^{a}$ | 12.88$^{a}$ | 32.95$^{a}$ |
| Genotypes | | | | | |
| Sahar | 40.64$^{ef}$ | 97.84$^{de}$ | 10.51$^{b}$ | 9.17$^{bc}$ | 15.98$^{bcd}$ |
| Super Perfect | 37.70$^{f}$ | 117.2$^{bc}$ | 8.700$^{cde}$ | 8.52$^{bc}$ | 31.44$^{a}$ |
| Paliz | 47.56d$^{e}$ | 123.7$^{bc}$ | 9.51$^{c}$ | 8.08$^{bc}$ | 17.77$^{abcd}$ |
| Saba | 65.38$^{a}$ | 131.0$^{ab}$ | 8.564$^{def}$ | 7.86$^{bc}$ | 15.27$^{bcd}$ |
| Vania | 37.71$^{ef}$ | 98.87$^{cd}$ | 8.415$^{def}$ | 13.5$^{abc}$ | 10.62$^{d}$ |
| Early Super Select | 33.42$^{f}$ | 98.27$^{cd}$ | 8.930$^{cd}$ | 14.92$^{ab}$ | 14.15$^{cd}$ |
| Savannah Sweet | 65.93$^{a}$ | 134.2$^{ab}$ | 7.488$^{g}$ | 7.446$^{c}$ | 28.87$^{ab}$ |
| Golden eye | 58.21$^{abc}$ | 121.1$^{bc}$ | 8.302$^{defg}$ | 8.3b$^{c}$ | 23.86$^{abcd}$ |
| Duster | 52.74$^{bcd}$ | 109.2$^{cd}$ | 10.40$^{b}$ | 8.05$^{bc}$ | 20.55$^{abcd}$ |
| SV6362 | 61.59$^{ab}$ | 143.9$^{a}$ | 7.936$^{efg}$ | 7.8$^{bc}$ | 31.21$^{a}$ |
| Amprialize | 52.23$^{cd}$ | 120.2$^{bc}$ | 8.022$^{defg}$ | 8.06$^{bc}$ | 19.15$^{abcd}$ |
| Behbahan improved population | 36.63$^{f}$ | 83.62$^{e}$ | 17.27$^{a}$ | 16.38$^{a}$ | 26.37$^{abc}$ |
| Primavera | 59.72$^{abc}$ | 134.3$^{ab}$ | 8.736$^{cde}$ | 7.86$^{bc}$ | 23.56$^{abcd}$ |
| Cyrus | 58.66$^{abc}$ | 133.2$^{ab}$ | 7.740$^{fg}$ | 8.326$^{bc}$ | 29.07$^{ab}$ |
| Texas Early Grano | 58.12$^{abc}$ | 128.7$^{ab}$ | 8.694$^{cde}$ | 9.58$^{bc}$ | 18.61$^{abcd}$ |

## Cluster Analysis

To estimate the genetic distance among different genotypes, the cluster analysis was worked out in the present study. Based on Ward method in cluster analysis, genotypes were grouped into four clusters for all the traits (Fig. 1). The cluster-I and Cluster-II accommodated maximum number of genotype (6) followed by cluster III (2), Cluster-IV (1) (Table 1). Cluster I consisted of hybrids No. 1, 2, 5, 6, 9 and 12 were not important for any of traits. Hybrids No. 3, 8, 11, 13, 14 and 15 subjected to cluster II was important for average bulb weight. Savannah Sweet hybrids (No. 7) and SV 6362 (No. 10) were in group III. Cluster III was important for high yield as well as high weight loss. Cluster IV with one genotype was important for high bulb yield and low weight loss. Saba hybrid (No. 4) with the highest bulb yield and lowest weight loss subjected as super hybrid (Fig. 1) (Table 1).

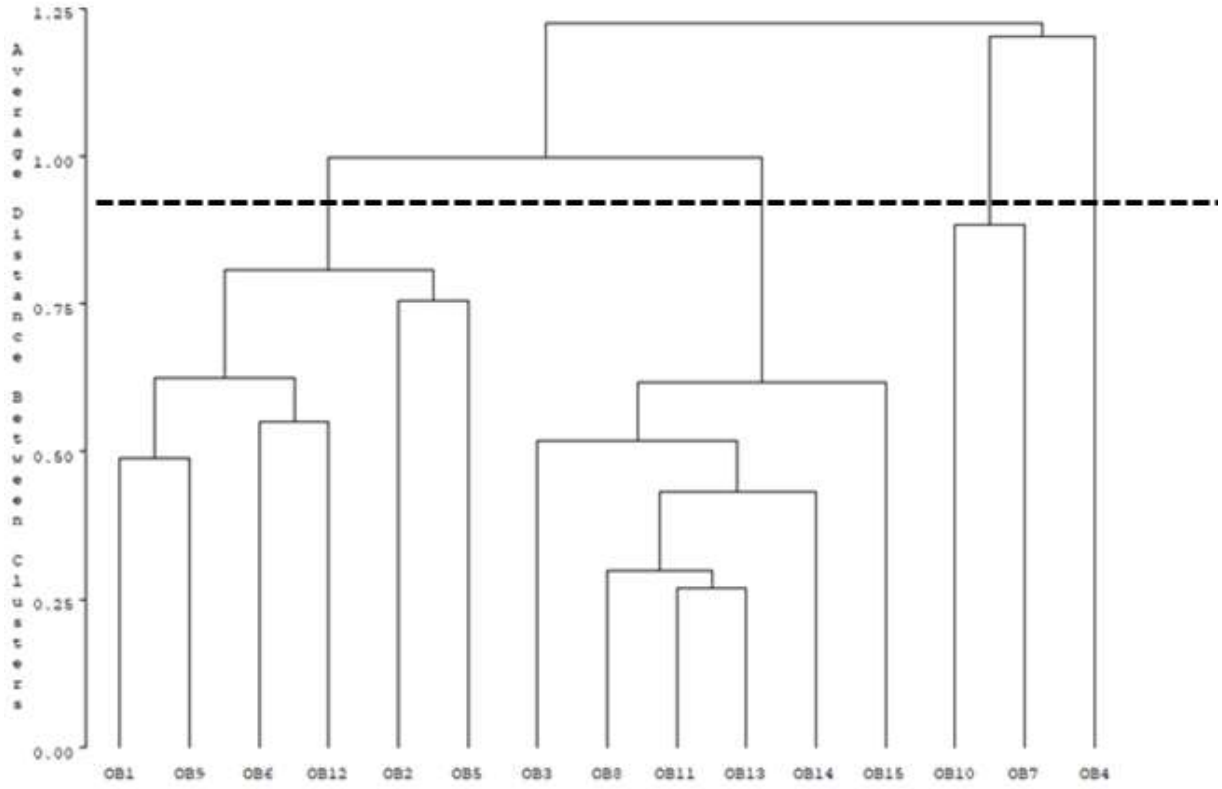


**Fig. 1.** Cluster analysis of short-day onion hybrids in Isfahan location for quantity and quality traits using Ward's method. The name of genotypes is given in Table 1.

## KHUZESTAN LOCATION

### *Mean comparison*

According to the results of mean comparison, SV 6362 hybrids, Saba and Savannah Sweet and Golden eye along with three controls showed bulb yield more than 80 t/ha with no difference Significantly, they were recognized as the best hybrids and in contrast to the Super-Select, Behbahan improved population, Eearly Super Perfect, Sahar and Vania hybrids with yields of less than 60 t/ha were identified as weak hybrids (Table 6). The average bulb weight ranges from 99.62 g to 199.03 g. Genotype SV6263 recorded highest bulb weight ranges, whereas Behbahan improved population recorded lowest bulb weight range. In this study, for this trait, SV6362, Saba and Savannah Sweet hybrids, with low and insignificant difference, weighed more than 180 g. The highest dry matter content (15.77%) with high significantly different from the other hybrids was obtained for Behbahan improved population; but, there was no significant difference among the other hybrids for dry matter content ranged from 7.04% to 9.90%. In term of total solids solution, Behbahan improved population with high significant difference registered the maximum value (14.75%). The other genotypes ranged from 6.08 (for Savannah Sweet) to 8.30 (for Texas Early Grano) with no significance difference. Weight loss was observed in the range of 4.34% for Saba cultivar to 19.84% for Cyrus. In terms of this trait, Sahar, Paliz, Saba and Vania hybrids were considered as genotypes with the lowest weight loss (Table 6).

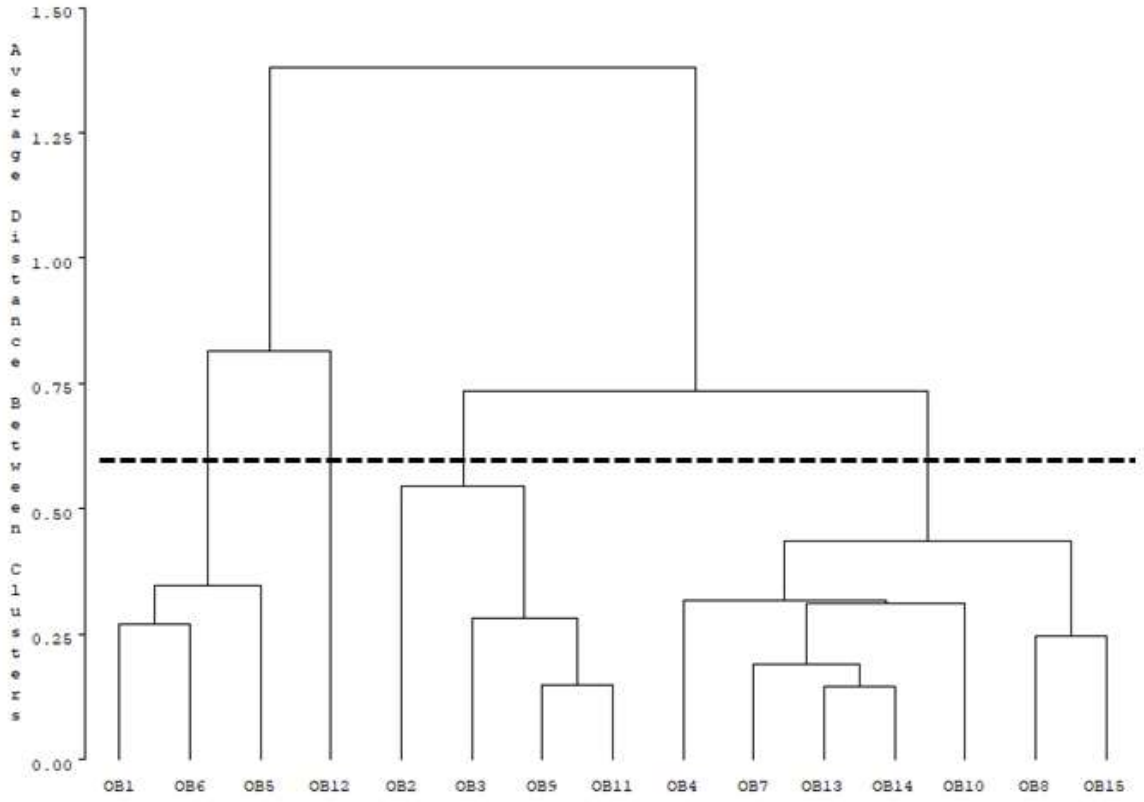


**Fig. 2.** Cluster analysis of short-day onion hybrids in Khuzestan location for quantity and quality traits using Ward's method. The name of genotypes is given in Table 1.

## Cluster Analysis

The results of cluster analysis by Ward's method (Fig. 2) divided the hybrids into four groups. According to the results of this study, the main difference between the genotypes was observed in two traits of bulb yield and weight loss; so, grouping was mostly based on these two traits. The cluster I, II, III contained 3, 1 and 4 genotypes, respectively and cluster IV had the maximum number (7) of genotypes. Hybrids No. 1, 5 and 6 (cluster I) recognized as low bulb yield and weight loss. Cluster II contained one genotype; Behbahan improved population and showed superior quality traits. Cluster III concluded hybrids No. 2, 3, 9 and 11 and finally hybrids 4, 7, 8, 10 along with controls were identified as a group with high yield and high weight loss. Only Saba hybrid had high bulb yield and low weight loss (Fig. 2) (Table 1).

**Table 6.** Mean comparison of quantitative and qualitative traits of short-day onion hybrids in Isfahan and Khuzestan regions using LSD (0.05) method

| Location | No. | Genotype | Bulb yield (t/ha) | Average bulb weight (gr) | Dry matter content (%) | Total soluble solids (%) | Weight loss (%) |
|---|---|---|---|---|---|---|---|
| Khuzestan | | | | | | | |
| | 1 | Sahar | 52.70de | 129.54i | 9.90b | 8bc | 5.24fg |
| | 2 | Super Perfect | 51.27de | 171.17def | 8.04c | 7.50b | 12.94bcde |
| | 3 | Paliz | 66.73bcd | 162.77fg | 8.11bc | 6.93bc | 4.79g |
| | 4 | Saba | 89.71a | 186.68bc | 7.71c | 6.53bc | 4.43g |
| | 5 | Vania | 56.35cde | 141.51h | 7.89c | 7.17bc | 6.08fg |
| | 6 | Early Super Select | 41.78e | 129.52i | 8.55bc | 6.87bc | 9.44f |
| | 7 | Savannah Sweet | 89.14a | 180.22bcd | 7.04c | 6.08c | 14.54bcd |
| | 8 | Golden eye | 85.38ab | 167.31efg | 7.88c | 7.12bc | 16.79ab |
| | 9 | Duster | 77.57ab | 156.53g | 8.3bc | 7.07bc | 9.14ef |
| | 10 | SV6362 | 92.38a | 199.03a | 7.05c | 6.67bc | 11.47cde |
| | 11 | Amprialize | 74.68abc | 161.44fg | 7.08c | 6.77bc | 10.57de |
| | 12 | Behbahan improved population | 48.70de | 99.62j | 15.77a | 14.75a | 17.09ab |
| | 13 | Primavera | 89.81a | 189.63ab | 7.04c | 6.41bc | 14.44bcd |
| | 14 | Cyrus | 87.32a | 186.23bc | 7.49c | 7.27bc | 19.84a |
| | 15 | Texas Early Grano | 88.27a | 176.11cde | 8.54c | 8.30b | 15.44bc |
| | | Mean | 72.69 | 162.70 | 8.41 | 7.50 | 11.49 |
| Isfahan | | | | | | | |
| | 1 | Sahar | 28.58bc | 66.13cde | 11.41c | 12.63b | 26.72b |
| | 2 | Super Perfect | 24.14c | 63.33de | 9.70cdef | 10.05cd | 49.94a |
| | 3 | Paliz | 28.40bc | 84.20ab | 11.60c | 9.80cd | 30.74ab |
| | 4 | Saba | 41.05ab | 75.23abc | 9.85cdef | 9.85cd | 26.10b |
| | 5 | Vania | 19.07c | 56.18e | 9.96cdef | 8.68d | 37.10ab |
| | 6 | Early Super Select | 25.06c | 67.02cde | 10.94cde | 9.75cd | 38.53ab |
| | 7 | Savannah Sweet | 42.72a | 84.84a | 8.16f | 9.50cd | 43.20ab |
| | 8 | Golden eye | 31.11ab | 74.92abc | 8.73f | 10cd | 30.93ab |
| | 9 | Duster | 27.90c | 61.85e | 13.80b | 11bcd | 31.96ab |
| | 10 | SV6362 | 30.80abc | 88.81a | 9.26ef | 9.50cd | 50.94a |
| | 11 | Amprialize | 31.11ab | 78.97abcd | 9.44def | 10cd | 27.72b |
| | 12 | Behbahan improved population | 24.57c | 67.61bcde | 19.52a | 18.84a | 35.92ab |
| | 13 | Primavera | 29.63bc | 78.9abcd | 11.29cd | 9.85cd | 32.49ab |
| | 14 | Cyrus | 30bc | 80.23abcd | 8.11f | 9.87cd | 38.30ab |
| | 15 | Texas Early Grano | 27.97c | 81.31abc | 8.93f | 11.50bc | 21.63b |
| | | Mean | 29.47 | 73.97 | 12.32 | 10.71 | 34.81 |

Means followed by the same letters in each column are not significantly different at 1% probability level according to LSD (0.05) test.

## DISCUSSION

### Quantity traits

The onion economic performance is the main purpose of onion production. Theoretically, onion yield is obtained by bulb density × average bulb weight. Therefore, with constant density, the bulb yield is directly related to the average bulb weight. In this study, Saba and SV6362, which had the highest bulb yield in both experiments, have the highest average bulb weight. The lowest average bulb weight was assigned to Vania, Early Super Select and Super Perfect, which had the lowest bulb yield. Only Duster hybrid showed high bulb yield (77.57t/h) and low average bulb weight (156.53 g) in Khuzestan. The bulb yield of three controls: Primavera, Cyrus and Texas Early Grano 502 in Khuzestan showed high bulb yield. In previous studies, high potential of Primavera for short day regions in the south of the Iran have been reported (Darabi & Salehi, 2014).

**Quality traits**

The important factors in bulb quality are dry matter content and total soluble solids which depend on the genotypes and environment factors. The results of this study showed the significant difference between Behbahan improved population and other hybrids in terms of dry matter content and total soluble solids in two experiments. These finding related to TSS are in agreement with the finding of Bal et al. (2020b) in onion. This superiority of the quality traits in Behbahan improved population has been reported in previous experiments (Darabi, 2015). The higher dry matter content and TSS value in this population may be due to its inherent characteristics.

**Weight loss**

Onion storability is necessary in order to preserve its quality and minimize losses during the marketing process and also for seed production (the fact that this crop is biennial) (Brewter, 2008). Weight loss is the important problem during onion storability. In fact, water is lost in onions through evaporation and respiration and is considered as weight loss, as a unit (Msuya et al., 2005). In this study, the average weight loss of bulb in Isfahan experiment (34.81%) was significantly higher than Khuzestan experiment (11.49%). Studies have shown that there is a direct and inverse relationship between neck diameter and dry matter percentage with weight loss in bulbs, respectively (Rostam Forudi, 2006; Darabi & Salehi, 2014). Their studies showed that increasing neck diameter and decreasing dry matter content in genotypes led to an increase in weight loss (Rostam Forudi, 2006; Darabi & Salehi., 2014). Considering the high average dry matter content of genotypes in Isfahan experiment (10.71%) compared to Khuzestan experiment (8.41%) and also, small neck diameter of these genotypes, it can be concluded that other factors function in weight loss. It seems that low number of skin to be one of the important reasons for high weight loss in Isfahan experiment. This means that in this study, the role of the number of skins in reducing bulb weight is more important than dry matter content and neck diameter. These results are consistent with Ramin (1999) and Darabi (2018) researches on the important and decisive issue of skin in weight loss.

In this study, genotypes showed significant different for weight loss in Isfahan and Khuzestan experiments. The type of damage caused by storability in two locations was different. In Isfahan, bulb spouting in the studied genotypes resulted in weight loss. In Khuzestan, the percentage of damage due to weight loss was gray rot. Behbahan improved population in the two environments showed a high level for this trait; this result is similar to the previous results of Darabi (2018). A study of the storability of eight onion populations during six months in uncontrolled storage showed that Behbahan improved population has the highest weight loss compared to the others, which is due to the low number of skins in this population (Darabi, 2018). Important factors in bulb weight loss can be: differences in diameter of the neck, differences in skin permeability, differences in sharpness and dry matter content of bulbs, and differences in skin thickness (Brewter, 2008). Rostam Foroudi (2006) reported several factors for onion weight loss including length of dormancy, variety disease resistance and dry outer scale thickness and adherence.

## CONCLUSION

In conclusion, considerable genetic variation among hybrids indicates that selection for increasing bulb yield and its components should be successful. Saba hybrid was identified as high bulb yield with low weight loss hybrid, Vania hybrid recognized as low bulb yield and the Savannah Sweet was identified as high yield with high weight loss in two experiments.

Thus, in future breeding programmes, emphasis should be given to Saba hybrid for producing high bulb yield and best quality onion variety.

**Conflict of interest**

The authors declare that there is no conflict of interest.

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