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Fruit, Seed Characteristics and Seed Yield of Some Bottle Gourds (*Lagenaria siceraria* Molina Standl.) Genotypes From Turkish Germplasm

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ABSTRACT
In this study, some fruit and seed characteristics and seed yield of a 22 genotypes of Turkish *Lagenaria siceraria* germplasm were determined. Ten seedlings from each genotype were transplanted with 3.0 m*0.5 m spacing to open field. 10 kg N da^{-1}, 10 kg P_2O_5 da^{-1} and 10 kg K_2O da^{-1} fertilizers were added to the soil during soil preparation. Fruit diameter, fruit length, fruit seed yield, 100 seed weight, seed width, seed length and seed thickness were determined in three replication with five fruits. While the fruit length was between 134.2 and 1.15 cm, the fruit diameter varied between 2.34 and 9.42 cm. LS31-09 produced the highest seed yield with 153.85 g $fruit^{-1}$, and the lowest seed yield was obtained from LS01-18 with 2.53 g $fruit^{-1}$. Genotypic variation was significant in 100 seed weight, and the 100 seeds weight with a mean of 20.1 g ranged from 3.7 g to 28.1 g. The fruit diameter was positively correlated with the seed yield per fruit, seed length and 100 seed weight. Overall, 100 seed weight was positively correlated with fruit seed yield, seed width and seed index, and a strong positive correlation between 100 seed weight and seed length. This study showed that Turkish bottle germplasm have high seed yield genotypes..

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Türkiye Genetik Kaynaklarından Bazı Su Kabağı (*Lagenaria siceraria* Molina Standl.) Genotiplerinin Meyve ve Tohum Özellikleri ve Tohum Verimi

ÖZET
Bu çalışmada, Türk su kabakları genetik kaynaklarından örnek bir grubun bazı tohum ve meyve özelikleri ile tohum verimi belirlenmiştir. Her genotipten 10 fide 3.0 *0.5 m aralıkla açık tarla koşullarına dikilmiştir. Toprak hazırlığı döneminde 10 kg N da^{-1}, 10 kg P_2O_5 da^{-1} ve 10 kg K_2O da^{-1} olacak şekilde gübre verilmiştir. Meyve çapı, meyve uzunluğu, meyve tohum verimi, 100 tohum ağırlığı, tohum genişliği , tohum uzunluğu ve tohum kalınlığı üç tekerrürlü olarak 5 meyvede belirlenmiştir. Meyve uzunluğu 1.15 ile 134.2 cm arasında değişirken, meyve çapı 2 ile 6 cm arasında değişmiştir. En yüksek tohum verimi 153.85 g $meyve^{-1}$ ile LS31-09 genotipinden alınırken, en düşük tohum verimi 2.53 g $meyve^{-1}$ ile LS01-18 genotipinde belirlenmiştir. Genotipik varyasyonun önemli olduğu 100 tohum ağırlığı 3.7 g ile 28.1 g arasında değişmiş ve ortalama 100 tohum ağırlığı 20.1 g olmuştur. Meyve çapı meyve başına tohum verimi, 100 tohum ağırlığı ve tohum uzunluğu ile pozitif korelasyon göstermiştir. 100 tohum ağırlığı meyve tohum verimi, tohum eni ve tohum indexi ile pozitif korelasyon gösteriken, tohum uzunluğu ve 100 tohum ağırlığı arasında güçlü pozitif korelasyon tespit edilmiştir. Bu çalışma, Türk su kabağı genetik kaynaklarının yüksek tohum verimli genotiplere sahip olduğunu göstermiştir.

Araştırma Makalesi

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Anahtar Kelimeler
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Meyve özellikleri
Tohum verimi
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Tohum büyüklüğü

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INTRODUCTION

Conservation and utilization of genetic resources are two basic steps of the inevitable processes in ensuring efficiency and sustainability in plant production. The most essential consistent way to cope with yield and quality reduction due to various stress (biotic and abiotic) factors can be the determination of genotypes resistant to the stress conditions among the available genetic resources. In sustainability and productivity of plant production, to the introduction of underutilized species is as critical as developing and delivering productive genotypes that are resistant to stress conditions. The orphan, abandoned, lost, poorly used, local, minor, traditional, alternative, niche or unimproved species which are known as neglected and underutilized species are also called forgotten or smart food. These crop species are domesticated plant species that have been cultivated for long times for their roots, leaf, stems, flowers, fruits, seed, fiber, oil or medicinal properties, however, they have lost their importance over time due to certain products and use restrictions. One of the well known underutilized vegetable species is the calabash (*Lagenaria siceraria* Standl. Moll) which was domesticated 12,000 years ago (Whitaker 1971).

Lagenaria siceraria, known as bottle gourd, is a member of the Cucurbitaceae family. Bottle gourd, which is extremely strong climbing, herbaceous and monoecious, is easily distinguished from other members of the Cucurbitaceous family with its large white flowers. It is a native species for Africa with its five wild species, and it is widely distributed in both hemispheres. Wild species of bottle gourd are *L. abyssinica* (Hook. f.) C. Jeffrey, *L. brevifilora* (Benth.) Roberty, *L. rufa* (Gilg) C. Jeffrey, *L. sphaerica* E. Mey. and *L. guineensis* (G. Don) C. Jeffrey (Decker-Walters et al 2001, 2004; Morimoto et al 2005). Cultivated *L. siceraria* with a pan-tropic dispersion was domesticated independently in both old and new worlds (Harris, 1967). On the other hand, Withaker (1971), who does not accept this theory, suggests that the bottle gourd which is native to Africa was carried to the American continent by ocean currents. Morimoto has reported that it had been distributed by the ocean currents or people migration. This ancient vegetable species has been produced for different purposes by humans in different parts of the world.

L. siceraria's young fruits are consumed as a vegetable in some African and Asian countries. Fresh and young fruits are consumed by making moussaka, frying or stuffing as in the summer pumpkins (*Cucurbita pepo*). Bottle gourd fruits can be cooked simply or mixed with other vegetables and foods. In some cases, fresh fruits are dried to consume when fresh fruits are not available. In some African countries, the young leaves, tendrils, and shoots of bottle gourds are consumed as leafy vegetables. After the inside of the ripe fruit (seed and spongy texture) is removed, they can be used in making kitchen cups, water flask, musical instrument, decorative stuff, water pipe or in some cases, fishing net floaters (Decker-Walters et al 2001; Morimoto et al 2005). Oil is also extracted from the bottle gourd seeds in some African countries (Loukou et al 2007; Mariod et al 2015). Young fruits, seeds, tendril, shoots, and young leaves extracts have been also used in some local drug mixtures (Herklots 1972; Moerman 1998; Manandhar 2002). Another use area of the bottle gourds is as rootstocks for some Cucurbitaceous species such as watermelon and cucumber against soil-borne diseases and some adverse soil conditions such as low temperature, salinity stress and excessive water (Lee 1994; Yetisir et al 2006; Karaca et al 2012). The watermelon grafting onto bottle gourd was performed first in Korea and Japan (Ashita 1927) in the late 1920s, and a high graft compatibility rate was determined (Lee 1994; Oda 1995; Yetisir and Sarı 2003).

Although *L. siceraria* is not an indigenous plant species for Turkey, morphological characteristics of fruit and seed show significant diversity (Yetisir et al 2008). As stated above, as in some African countries, bottle gourd has been also grown for several purposes such as food, containers, music instruments and decoration equipment depending on the fruit characteristics in Turkey, especially in rural areas (Yetisir et al 2008). In plant production, characterization and evaluation of plant germplasm according to their intended use is one of the crucial issues. As mentioned above, bottle gourds are used for oil extraction and rootstocks for some Cucurbitaceous species. Seed yield is an important criterion for rootstock production and in producing oil from seeds. Amangoua et al (2018) reported a higher seed yield in calabash type bottle gourds and they determined significant heterosis in seed and 100 seed weight when calabash types were used as the maternal parent. A substantial variation among bottle gourd landrace in seed dimensions and seed yield was also reported by Buthelezi et al (2019). Bottle gourd plants grown in a trailing system produced more seed yield with high quality than the traditional growing system (Sharma et al 2016). According to our knowledge, the previous study on seed yield and seed production in *L. siceraria* is limited and there is no study about seed yield and production in Turkish bottle gourds genotypes. Therefore, the current study aimed to determine seed yield and characteristics of *L. siceraria* sampled from Turkish bottle gourd germplasm.

MATERIAL and METHODS

The codes and collection sites of 22 bottle gourds genotypes used in this study were given in Table 1.

Table 1. Code, collection sites and fruit shape of the bottle gourd genotypes.

Genotypes	Collection locations	Fruit shape
LS01-16	Çukurova University, Department of Horticulture, Adana	Bottle
LS01-17	Çukurova University, Department of Horticulture, Adana	Bottle
LS01-18	Çukurova University, Department of Horticulture, Adana	Bottle
LS07-04	Mahmutlar, Alanya	Bottle
LS07-06	Dim çayı, Alanya	Elongated
LS07-42	Turuncova, Finike	Pyriform
LS07-45	Şahin tepesi, Kumluca ,Antalya	Pyriform
LS09-01	Horsunlu, Aydın	Bottle
LS20-02	Hisar Village- Denizli	Bottle
LS20-06	Tavas, Denizli	Bottle
LS31-08	Büyük çat Village, Samandağ, Hatay	Club
LS31-09	Karaağaç, Iskenderun,Hatay	Club
LS31-43	Hassa, Hatay	Bottle
LS33-02	Karakaya Village, Silifke - Mersin	Bottle
LS33-15	Kızkalesi, Silifke, Mersin	Bottle
LS33-35	Elvanköy, Erdemli, Mersin	Elongated
LS33-41	Çerçi Village, Erdemli, Mersin	Bottle
LS33-45	Adanalıoğlu,Mersin	Pyriform
LS35-01	Şirince, Selçuk, Izmir	Bottle
LS46-03	Efirağzı Village, Andırın, Kahramanmaraş	Bottle
LS47745	Yavuzeli, Gaziantep	Club
LS48-07	Saklıkent, Fethiye, Muğla	Club

Seeds of the bottle gourd genotypes were sown in multipots filled with a potting mixture consist of peat and perlite (1:1) on 17.03.2004 in an experimental greenhouse of Horticultural Department, Agricultural Faculty of Mustafa Kemal University. Ten seedlings from each genotype with 2-3 true leaves were planted with 3.0 * 0.5 m spacing to open field conditions which was located on 36°18' 22" N, 36° 13' 33" E and elevation above sea level is 82 m. The average annual precipitation for the experimental region is 1,125 mm and varies between 570 and 1,160 mm and the soil is characterized as sandy-loam having a low amount of lime (Yetişir et al 2008). 10 kg N da^{-1}, 10 kg P_2O_5 da^{-1} and 10 kg K_2O da^{-1} chemical fertilizers were added to the soil during soil preparation. Plants were watered with drip irrigation depending on soil and plant observations. Fruit length and diameter (cm), fruit seed yield (g and number), 100 seed weight (g), and seed dimensions (length-cm, width-cm and thickness-mm) were determined with three replication in five fruits. The length of the fruit was measured with a ruler as the distance between the peduncle attachment point and the blossom end, while the diameter was calculated from the circumference measured with the help of a tape measure from the widest part of the fruit. Seeds were extracted from mature dry fruit manually for recording seed yield and morphological characteristics. 100 seed weight was determined with 0.01 precision balance. The seed length and width were determined in cm with a ruler, while the seed thickness was measured in mm with a digital caliper.

Statistical Analysis

Data was subjected to variance analysis according to randomized plot experimental design by using SAS Statistical Software (SAS 9.0, SAS Institute Inc., Cary, NC, USA). The means were compared by Tukey test at 0.01 and 0.05 significance levels. Correlation analysis was performed to determine the relationship between the investigated parameters.

RESULTS and DISCUSSION

A significant variation among bottle gourd genotypes in terms of fruit dimensions was observed. Fruit length was significantly affected by genotypes. While the longest fruit was determined in LS33-35 with 134 cm, LS01-18 had the shortest fruit with 1.15 cm. Mean fruit length was calculated as 52.45 cm. The difference between the longest fruit genotype and the shortest fruit genotype was calculated as 117 folds. The genotypes 07-06, 33-35 and 47745 were significantly different from other genotypes in terms of fruit length. Bottle gourd genotypes segregated into three distinct groups as regarded to fruit length. Bottle gourds are divided into three groups in terms of fruit sizes. These groups are long (33-35, 07-06 and 47745), short (01-18) and medium (others 18 genotypes) (Table 2, Figure 1). As in fruit length, fruit diameter was also significantly affected by genotypes and fruit diameter varied from 2.34 cm to 9.42 cm with 7.85 cm average. The largest diameter fruits were produced by the genotype 07-06 with 12 cm, while the fruits with the smallest diameter were harvested from the genotype 01-18 with 2.2 cm. Variation in fruit length was found higher than the fruit diameter (Table 2 and Figure 2). Fruit index (Fruit length/fruit diameter) was calculated, and it ranged from 2.2 (01-18) to 23.94 (33-35) with 6.9 average (Table 2). At the present study, a significant phenotypical difference was found in fruit shape and volume. While a higher variation was determined in fruit length than Mashilo et al. (2016) and Buthelezi et al. (2019) reported, a lower variation in fruit diameter than the two previous studies was determined. Significant variability in fruit characteristics of bottle gourd accessions from different part of Kenya (Morimoto et al 2005), from the southern part of Turkey (Yetisir et al 2008), Serbia (Mladenović et al 2009) and South Africa (Buthelezi et al 2019) were reported. As in Africa, the genetic origin of the bottle gourd species (Morimoto et al 2005), as well as in other parts of the world, morphological features such as fruit dimensions and shape have been important traits in the description of local bottle gourd landraces. More recently, Mashilo et al (2017) reported that presence or absence of fruit neck, fruit shape, degree of neck bending and fruit neck length positively correlated the phenotypic variation of South African bottle gourd landraces. In the family of squash (Cucurbitaceae), the significant range of fruit phenotypic variation has been also indicated in *C. pepo* (Paris 2001), *Citrullus lanatus* (Maggs-Kölling et al 2000; Gusmini 2003), *L. siceraria* (Morimoto et al 2005; Koffi et al 2009; Buthelezi et al 2019) and *C. maxima* (Balkaya et al 2010).

Table 2. Descriptive statistics of bottle gourd genotypes based on some morphological fruit and seed characteristics

	Fruit length (cm)	Fruit diameter (cm)	Fruit index	100 seed weight (g)	Seed yield per fruit (g)	Seed number per fruit	Seed length (cm)	Seed Width (cm)	Seed thickness (mm)	Seed index
Minimum	2.53	2.34	2.2	3.7	2.53	68.38	0.7	0.44	0.24	1.84
Maximum	153.85	9.42	23.41	28.06	153.85	691.77	2.18	1.03	0.39	3.11
Mean	52.20	7.85	6.94	20.14	64.97	315.81	1.84	0.76	0.33	2.44

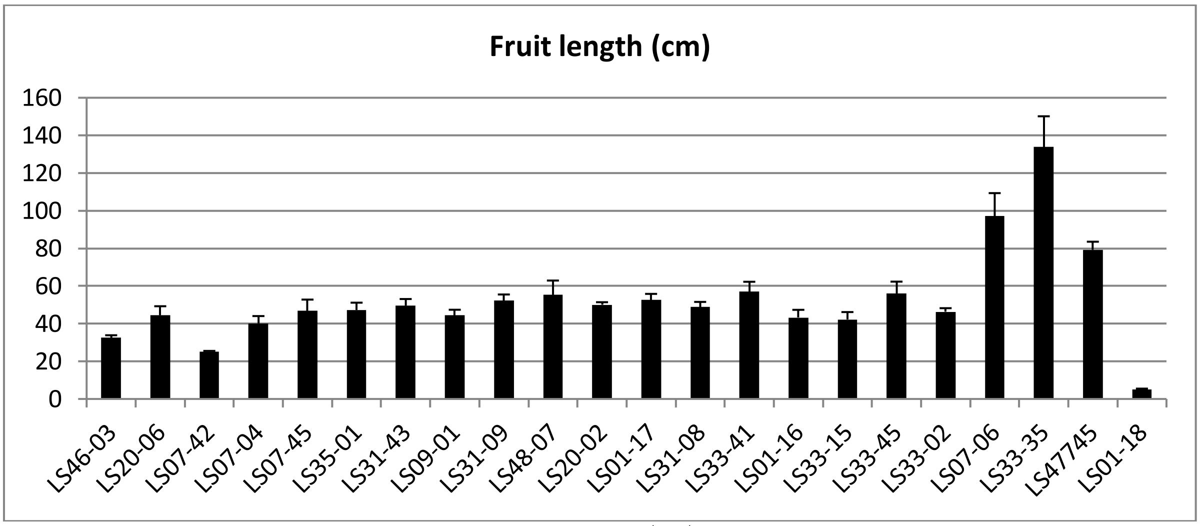

Figure 1. The fruit length of bottle gourd genotypes (cm). *P<0.01; Lsd: 9.531.*

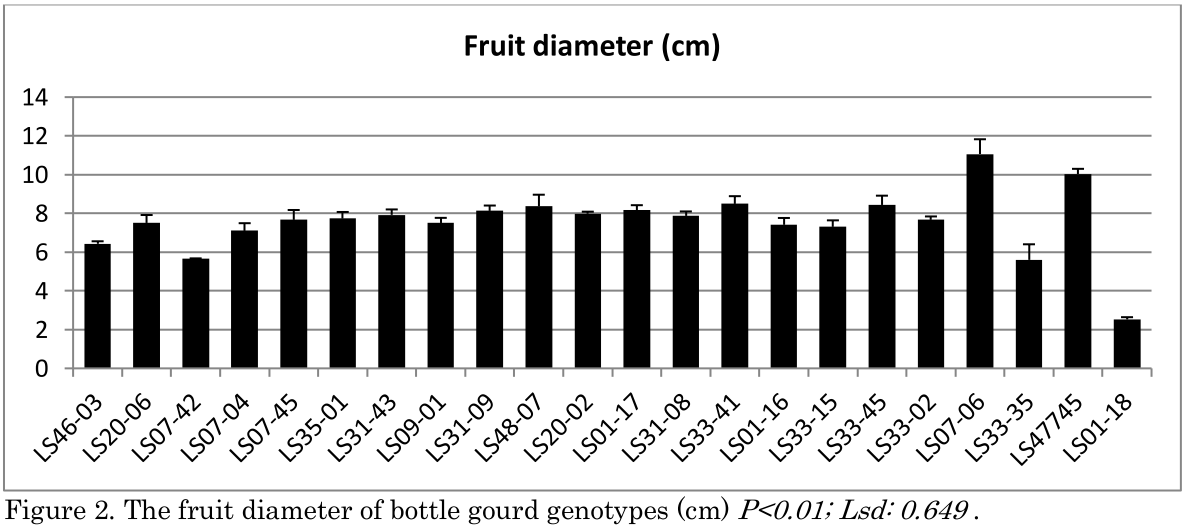

Figure 2. The fruit diameter of bottle gourd genotypes (cm) *P<0.01; Lsd: 0.649* .

Seed yield per fruit showing significant variation is summarized in Figure 3. While seed yield per fruit raged from 2.53 g/fruit^{-1} to 153.85 g/fruit^{-1} with, mean seed yield per fruit was calculated as 64.97 g/fruit^{-1}. The highest seed yield per fruit was determined in 31-09 with 153-85 g /fruit^{-1}, followed by 47745 and 31-43 and the lowest seed yield per fruit was determined with 2.53 g /fruit^{-1} in 01-18.

Similar results were obtained in the number of seeds per fruit. The number of seeds per fruit was significantly influenced by the bottle gourd genotypes, and the number of seeds per fruit having an average of 316 seeds ranged from 68 to 962 seeds per fruit. While the highest number of seeds per fruit was determined in the genotype LS31-09, it was followed by LS 31-43 and the least seed number per fruit was found in genotype LS 01-18 (Figure 4).

Seed size (100 seed weight) and shape showed significant diversity depending on genotypes (Figure 5, Figure 9). 100 seeds weight with an average of 20.14 g varied from 3.7 g to 28.06 g. The heaviest seeds were produced by LS 20-06, LS 01-16, LS 33-02, LS 33-45 and LS 33-41, respectively, while the lightest seeds were harvested from 01-18 (Figure 5).

A significant variation was found in seed length among bottle gourd genotypes. Seed length ranged from 0.7 to 2.18 cm, while average seed length was calculated as 1.84 cm. The longest seeds were harvested from LS 33-41 with 2.2 cm and the shortest seeds were obtained from LS 01-18 with 0.7 cm. A difference of more than three folds was found between the longest seeds and the shortest seed. While the number of genotypes having a longer seed length than the mean was 14, the other eight genotypes had seeds that were shorter than the average.

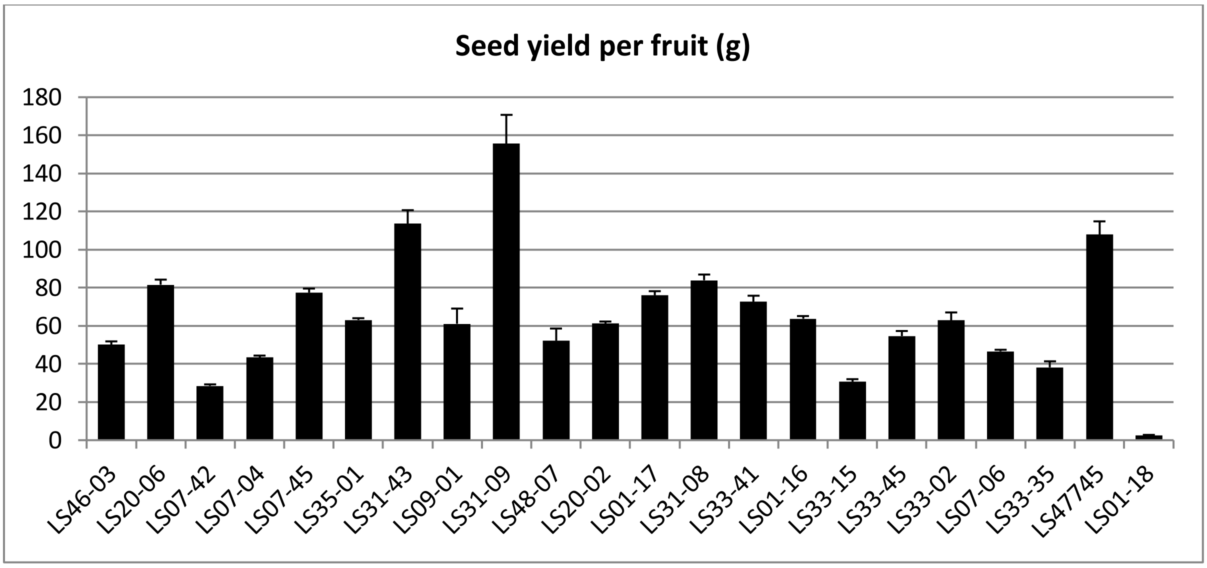

Figure 3. Seed yield of bottle gourd genotypes (g/fruit^{-1}), *P<0.01; Lsd: 7.922.*

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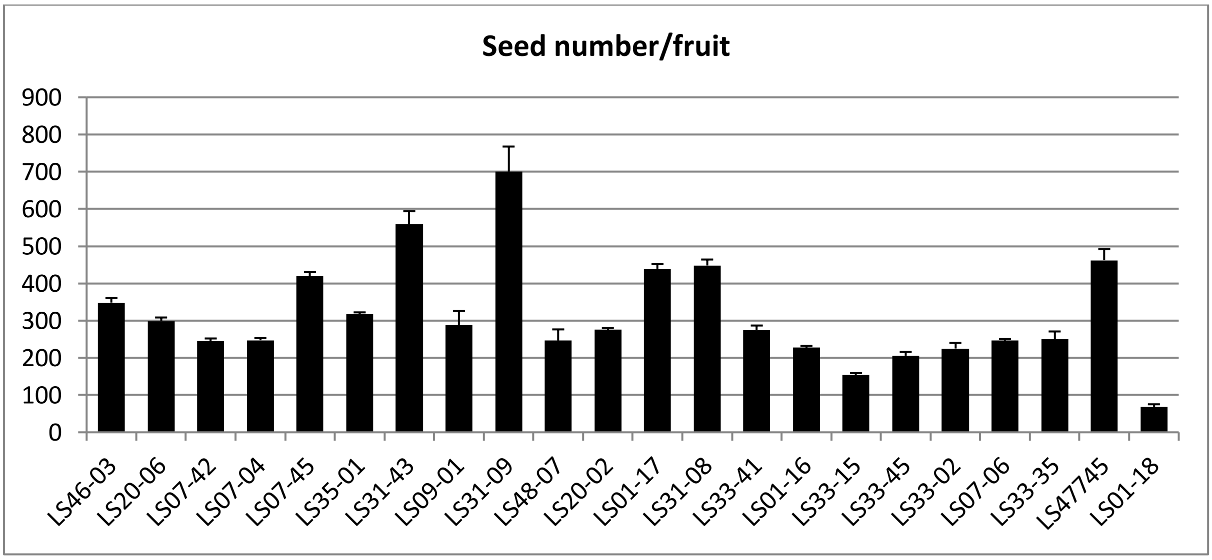

Figure 4. Seed yield of bottle gourd genotypes (seed number/fruit^{-1}), *P<0.01; Lsd: 36.706.*

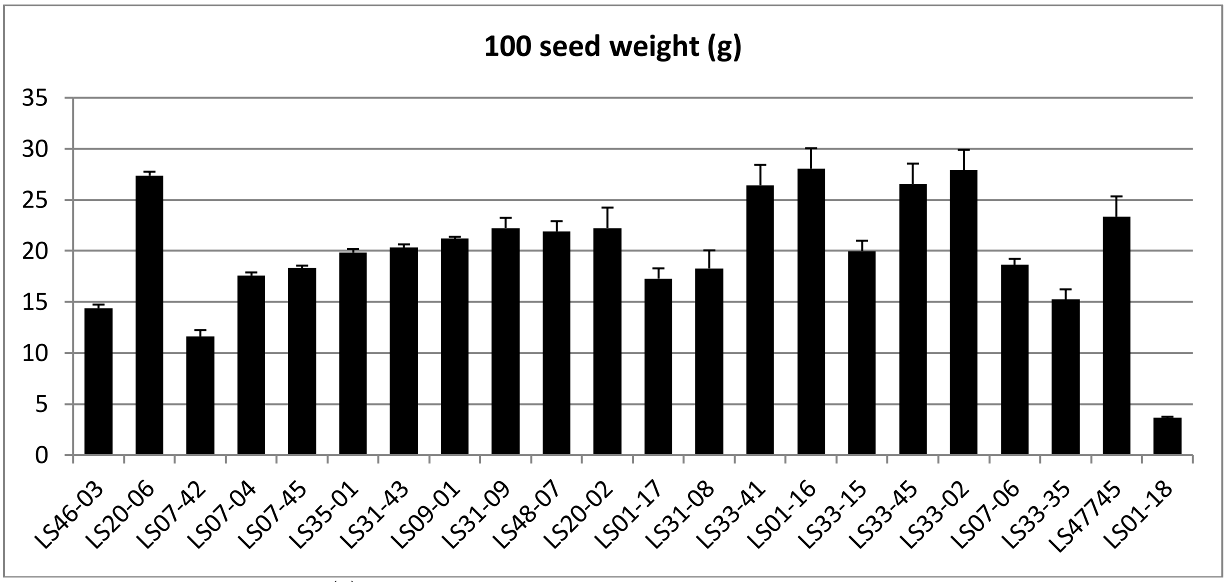

Figure 5. 100 seed weight (g), *P<0.01; Lsd: 2.032.*

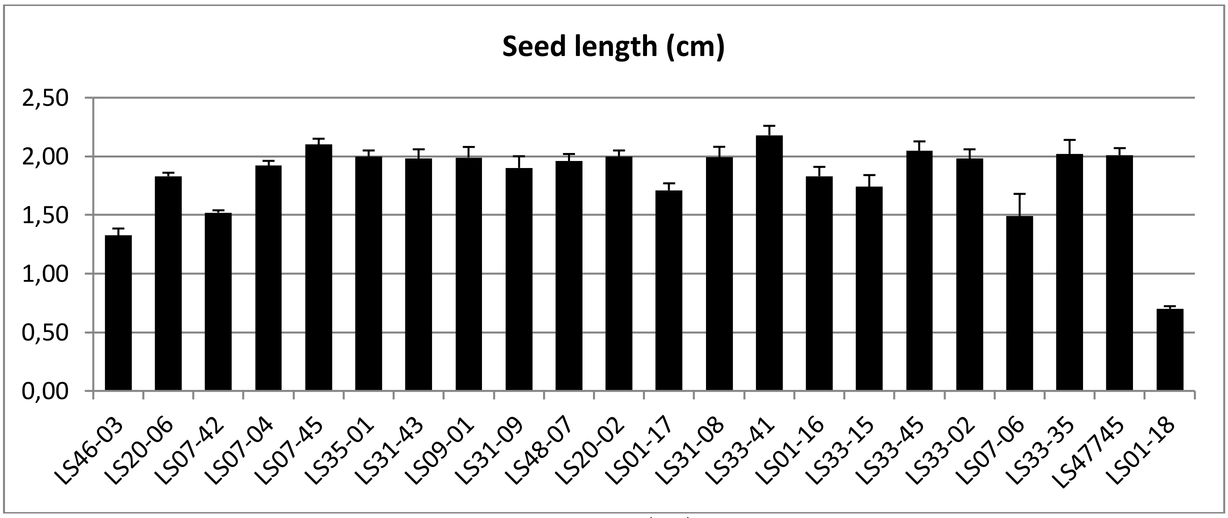

Figure 6. The seed length of bottle gourd genotypes (cm), *P<0.01; Lsd: 0.133.*

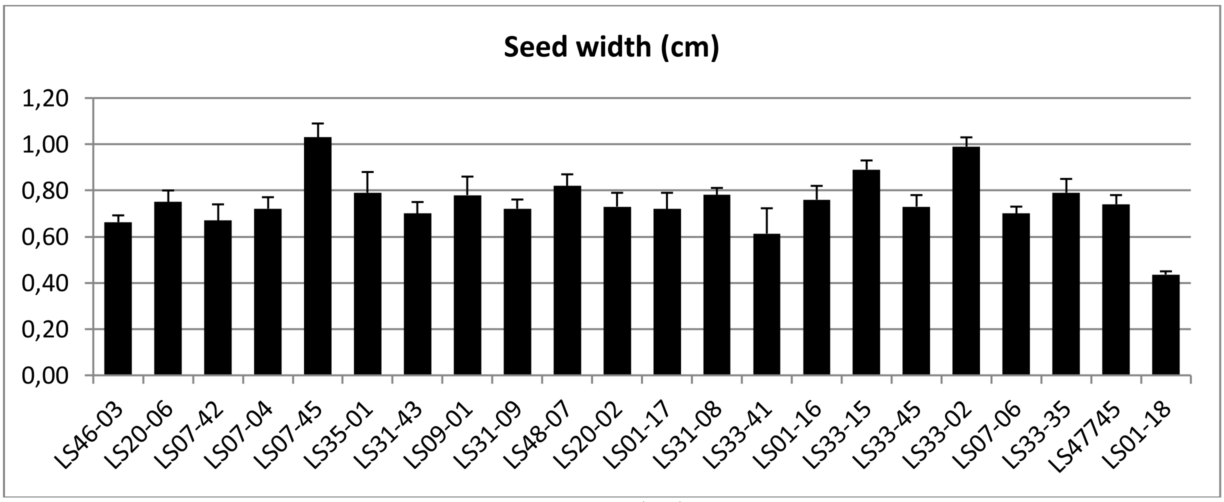

Figure 7. The seed width of bottle gourd genotypes (cm), *P<0.01; Lsd: 0.094.*

Seed width showed significant variation among bottle gourd genotypes. Seed width changed between 0.38 cm and 1.03 cm. While the largest seeds were determined in genotype LS 07-45 and LS 33-02 with 1.03 cm and 0.99 cm respectively, the narrowest seeds were determined in genotype LS 01-18 with 0.44 cm. The average seed width was calculated as 0.76 cm, and the number of genotypes having a seed width higher than the average seed width was 8 (Figure 7).

Findings related to seed thickness are given in Figure 8 and differences between genotypes were found significant. As shown in Figure 8, seed thickness ranged from 0.24 mm to 0.39 mm with 0.33 mm average. While the thickest and thinnest seeds were harvested from genotype LS 01-18 and LS 48-07 with 0.39 mm and 0.24 mm, respectively, the average of the seed thickness was calculated as 0.33 mm. As in fruit index, seed index also showed significant variation. It varied from 1.84 to 3.11 (Table 2, Figure 9).

Correlation coefficients were given in Table 3. While the fruit length was found positively correlated with the fruit diameter, it was strongly positively correlated with the fruit index. The fruit diameter was positively correlated with the seed yield per fruit (g) and strongly positively correlated with 100 seed weight and seed length. 100 seed weight was positively correlated with seed yield per fruit (g), seed width and seed index, and it was strongly positively correlated with seed length. The seed yield (g) per fruit showed a positive correlation with the seed index and a strong positive correlation with the number of seeds per fruit. The seed length had a strong positive correlation with seed width and seed index.

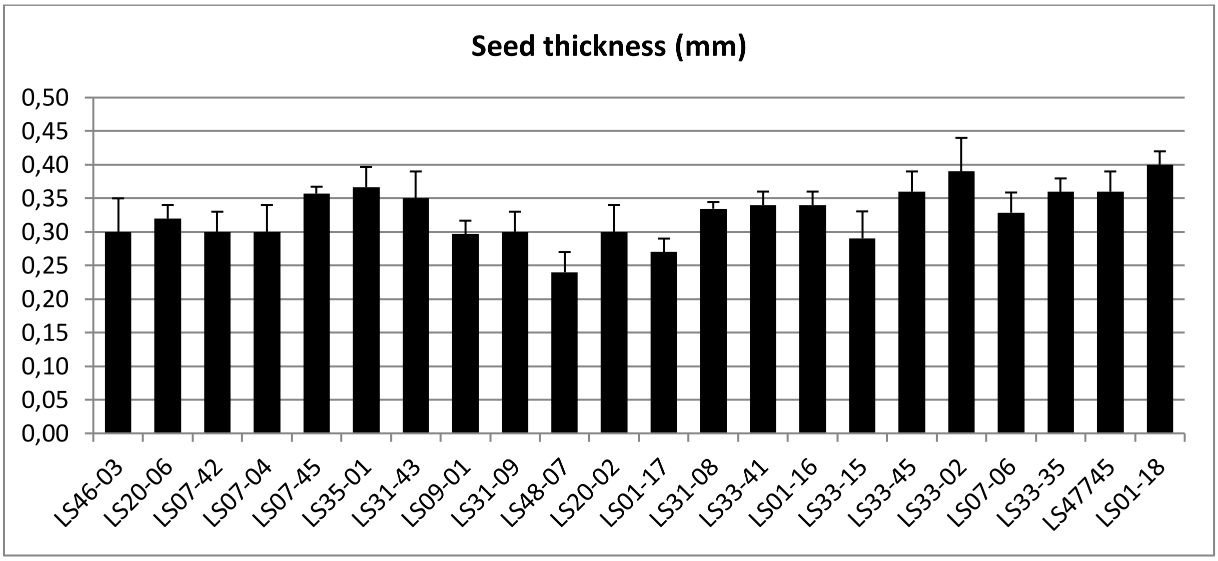

Figure 8. The seed thickness of bottle gourd genotypes (mm), *P<0.01; Lsd: 0.051.*

Figure 9. Seed shape and size of bottle gourds from Turkish bottle gourd germplasm.

Table 3. Correlation coefficients between investigated fruit and seed characteristics (n=66)

	Fruit diameter	Fruit index	100 seed weight	Seed yield	SN. Per fruit	Seed length	Seed width	Seed thickness	Seed index
Fruit length	0.96***	0.97***	0.21	0.16	0.14	0.41	0.21	0.07	0.27
Fruit diameter		0.360	0.40	0.52*	0.39	0.55**	0.33	-0.18	0.36
Fruit index			0.01	-0.02	0.02	0.31	0.16	0.12	0.20
100 seed weight				0.49*	0.17	0.70**	0.42	-0.05	0.45*
Seed yield					0.92***	0.52*	0.17	-0.04	0.42*
SN. per fruit						0.36	0.12	-0.11	0.30
Seed length							0.58**	-0.01	0.63**
Seed width								0.01	-0.24
Seed thickness									-0.04

SN: Seed number; *, **, *** significant at 0.05, 0.01, 0.001 respectively.

Seed characteristics and seed yield presented significant variation based on bottle gourd genotypes. In the family of squash (Cucurbitaceae), the significant variation in seed shape and seed yield has been also indicated in *C. pepo* (Paris 2001), *Citrullus lanatus* (Maggs-Kölling et al 2000; Gusmini 2003), *L. siceraria* (Pradhan et al 2013; Buthelezi et al 2019) and *C. maxima* (Balkaya et al 2010). In agreement with our results, a significant variation in seed characteristics of bottle gourd was previously reported from different parts of the world (Morimoto et al 2005; Mladenović et al 2009; Amangoua et al 2018; Buthelezi et al 2019). Significant variation in seed characteristics of Turkish bottle gourds was reported in previous studies (Yetisir et al 2008; Taş et al 2019). This variation in the Turkish gourd is attributed to the introduction of bottle gourd from different places and the high rate of cross pollination of bottle gourd. As can be seen from the seed shapes given in Figure 5, it was determined that all bottle gourds genotypes used in our study belong to the calabash group except for 01-18 with small fruit and seed size. Similarly, lower seed yield and smaller fruits were reported in oleaginous types bottle gourds by Amangoua (2018). 100 seeds weight (3.70-28.06 g) and seed yield per fruit^{-1} (2.53-153.85 g/fruit^{-1} and 68.38-691.77 seed per fruit) were in accordance with Sharma et al. (2016), Amangoua et al (2018) and Buthelezi et al (2019). Average calculated seed yield for calabash types is higher (1400 kg/ha^{-1}) than seed yield Sharma et al. (2016) reported in conventional growing methods. While the results of the seed length and seed width were in agreement with Buthelezi et al (2019), their average values were 1.84 and 0.76 cm, respectively. As reported in Saharma et al (2016) and Buthelezi et al (2019), seed size and fruit size were significantly positively correlated with seed yield. Since bottle gourds can climb, they can be grown vertically (trailing). With this growing system, it is possible to increase the seed yield by planting more plant to the unit area. Sharma et al (2016) reported a 15% increase in seed yield per fruit and 11% increase in seed yield per unit area by using the trailing method. This study showed that calabash type bottle gourds produced significantly higher seed than *Cucurbita pepo* (1200-1300 kg ha^{-1}) (Tuik 2018), and egusi melon (770-1020 kg ha^{-1}) (Emeka 2015). The high seed production capacity of the bottle gourds (Achigan-Dako et al 2006) with high adaptability to different adverse conditions can be used as an alternative oil source to vegetable oils (Loukou et al 2012). Variation in seed yield and seed physical properties are important for *C. pepo*, watermelon and bottle gourds grown for seed production. In seed production, both seed yield of genotypes and end-use purpose of seed are important. Producers demand high yielding varieties suitable for confectionary (*C. pepo* and watermelon) or oil extraction (bottle gourd). The high genetic diversity is the only important powerful tool in the hands of plant breeders. The higher the genetic diversity, the stronger the breeder's hand. In this regard, it was seen that Turkish bottle gourd germplasm has a significant variation in both seed yield and seed characteristics.

CONCLUSION

It was determined that all bottle gourd genotypes used in the present study belong to calabash type except for LS 01-18. Fruit and seed morphology and seed yield showed significant variation. All bottle gourd genotypes had larger seeds and higher seed yield than previous studies except for LS01-18 which have the smallest fruits and seeds. As suggested by Amangoua et al (2018), calabash type genotypes should be selected as a female parental line in hybrid seed production. It can be concluded that bottle gourd with a significant amount of oil and protein in its seeds can be an alternative oil plant with high seed productivity. *L. siceraria,* one of the underutilized species, genotypes from Turkish bottle gourd germplasm showed considerable potential in seed yield and this potential can be exploited in the future oil plant or rootstocks breeding program.

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