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Evaluation of vegetative growth, yield and yield components of eggplant (*Solanum melongena* L.) genotypes under the weather conditions of Al-Kharj region in Saudi Arabia

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Abstract
Two years field experiments were conducted, to evaluate of five eggplant i.e. Balady Black, Black Beauty, Florada Market, Selection2 and Selection3 genotypes on the vegetative growth, yield and its components traits of eggplant under the Al-Kharj region, Saudi Arabia conditions during the seasons of 2018 and 2019. Plant height (cm), number of branches on the plant, days to 50% flowering, fruit length (cm), fruit diameter (cm), Fruit Weight (g), early yield (ton / fed) and total yield (ton / fed) were determined. The results indicated that there were significant differences in all studied characters in both studied seasons. The highest values of plant height were obtained from both genotypes strain Selection 3 and Black balady. The highest value of number of branches on the plant was obtained from cultivar Black Beauty. Both Selection 3 and black balady genotypes were exhibited earlier genotypes for days to 50% flowering in 2018 and 2019 season respectively. The highest fruit length was obtained from eggplant genotype Florada Market 10. Black beauty was significantly higher than other genotypes for fruit diameter character in both studied seasons. While, Florada Market 10 genotype showed the highest values for fruit weight. Both eggplant strain Selection 3 and Black Beauty gave the highest values of early yield. On the other hand, Black Beauty exhibited the highest values for total yield and was significantly higher than other eggplant genotypes under Al-Kharj region conditions.

Keywords: *Solanum melongena* L, vegetative chracters, yield and its components, high temperature conditions

Introduction

*Solanum melongena (*Eggplant) is one of the utmost important and widespread vegetable fruit crops and is considered as a nationwide diet in several tropical and sub-tropical countries. Eggplant also known as Brinjal or Aubergine, is one of the non-tuberous species of the solanaceae or night shade family (Kantharajah *et al*. 2004). [17] Egg plant varieties show a wide range of fruit shape, colors, ranging from egg- shaped or oval to long cub shaped and from yellow, white, green with purple pigmentation to nearly black. Brinjal fruits are identified for being low in calories and having a higher amount of mineral content which is beneficial for human health. Zenia and Halina (2008) [38] also stated that eggplant is an ultimate source of potassium (k), magnesium (mg), calcium (ca) and iron (Fe). The yield and quality of eggplant depends on several cultural and environmental factors. Eggplant cultivars vary with several agronomic traits like; branching habit, time of flowering, time of fruit maturity and fruit yield (Osei*et al*. 2010). [26] Wide range of morphological, physiological and biochemical variation exists in different species and wild types of eggplant (Daunay *et al*., 1991; Collonier *et al*. 2001). [7, 14] Frary *et al*. (2007) [14] reported that fruit size, shape, color and taste are the utmost conspicuous characters that vary among different varieties. Warm climate vegetable species like eggplant, grown in the temperate zone, are exposed to abiotic and biotic environmental stress which limits the growth and development, crop yield, pre and postharvest fruit quality. Unfavorable environmental factors persuade physiological, biochemical and cytological alterations, which could be irreversible or reversible, depending on their intensity and duration. Chinnusamy *et al*. (2006) [6] reported that cell membrane is the primary sensor of physical stress, because a direct reduction in its liquidity during stress. Kaizi and Chen (2005) [16] reported that the heat tolerance level varied with the different seedlings. Drought or heat stress caused an increase in proline content and intensified electrolyte leakage. It appears that the electrolytes leakage, reflecting the degree of damage to cell membranes, can be a good determinate of eggplant seedlings tolerance level. Although the temporary increase in permeability of the cell membranes under the stress conditions can be observed there, it may be one of the features acquired by the plants that helps to enhance their resistance to stress. The effect of this process is activation of the “stress memory” and cross resistance to another stressor. Although eggplant is a warm season crop, low plant growth rate and bitter tasting fruits can be caused by dry condition and excessive heat (Azadeh *et al*., 2014). [4] Eggplant fruit marketability is mostly reduced by sun scalding which is caused by extremely high temperatures during the drought. Growth reduction, less fresh and dry biomass yield are the most obvious effect of water stress (Azadeh *et al*., 2014). [4] Drought stress causes closure of stomata and reduction in leaf area which translates to decline in photosynthetic pigments and activity (Amira, 2014). The most limiting factor affecting crop production worldwide is water deficit (Nuruddin, 2001). [25] Slow growing plants are associated to be growing under sub-optimal moisture levels and, in severe cases, dieback of stems such plants are less tolerant to insect attack and more susceptible to disease (Wilson, 2009). [37] Reduced yields in eggplant production have been associated

to water stress. The main consequence of inadequate moisture level for eggplant is decreased growth, development and production. Poor-quality eggplant results from long periods of hot, dry weather. It is very crucial to maintain the growth of plants by being able to recognize early symptoms of water stress which are wilting and the bottom leaves may turn yellow (Bauder, 2009). [5] Irrigation water is considered as one the main factors that greatly Affect on plant growth and productivity of eggplant. The appropriate irrigation time and level can play a significant role in enhancing the water use efficiency and the productivity of eggplant. On the other hand, the improper irrigation interval can lead to the development of water deficit in vegetable crop and result in a reduced yield and quality due to deficiency of water and nutrient. Abd El- Aal *et al*. (2008) studied the effect of water regime treatments on yield and its components of eggplant. They also recorded the better plant growth, heavier early and total yield when the eggplant irrigated at 10 days intervals. Yield and quality of crop depends on variety and the hybrid varieties have numerous advantages compare to the local varieties. Good vigor, trueness to type, maximum yields and uniformity are the important characters of hybrid variety. Plant characteristics like as earliness, disease resistance capacity and good retention ability have been introduced into most vegetable hybrids. Uniform plant habit and maturity, uniformity in size or shape have made hybrid vegetables tremendously suitable for commercial cultivation.

Materials and Methods

Seed of five eggplant genotypes i.e,, Balck Beuty, Black balady, Floraded Market, and two strains, Selection 2 and Selection 3 commercially grown at southern regions of Saudi Arabia at Alkharj governorate. The eggplant genotypes were transplanted in early summer to tested their performance under heat stress conditions. The monthly maximum and minimum temperature during growing seasons 2015 and 2016 at Al-Kharj, Saudi Arabia, were show in Table 1.

Table 1: The degree of temperature during growing seasons 2018 and 2019 At Al-Kharj, Saudi Arabia.

Season	2018		2019	Season		2018		2019	
Month	Max. temp	Min. temp.	Max. temp	Min. temp.	Month	Max. temp	Min. temp.	Max. temp	Min. temp.
Jan.	28	12	28	14	Jul.	44	29	46	31
Feb.	24	15	30	18	Aug.	42	27	45	30
Mar.	25	17	35	18	Sep.	37	24	36	23
Apr.	31	22	40	19	Oct.	33	23	34	23
May.	38	25	44	28	Nov.	27	17	28	17
Jun	43	28	45	30	Dec.	23	12	25	13

Seeds of eggplant genotypes were sown in seedling trays each with 60 wells of 5 mm × 5 mm under net house at 20 Aug. in both seasons 2018 and 2019 respectively. Four weeks later (20th September), the eggplant seedings were transplanted in the field in both seasons. The eggplant seedlings were grown in the field by using surface drip irrigation system. The experimental field was leveled precisely for installing the drip irrigation systems and then the dripper lines were installed on the soil surface of the experimental plot. The row spacing (distance between the dripper lines) was 80 cm and the distance between each two plants (distance between the drippers was 50 cm. The RAIN BIRB LD-06-12-1000 Landscape drip 0.9 G/h (4L/h) @ 18 " type dripper lines were collected from the irrigation accessories market in Jeddah, Saudi Arabia. For convenient flushing, the downstream end of each dripper was linked to a manifold in the plot. The inlet pressure on each tape was about 1.5 bars and 125-micron disk filter used in the system. Two tanks always full of water via main irrigation system in the field for continuous water supply in the experimental plants. All agriculture practices including irrigation, fertilization, Weeding and pests control were performed as recommended for eggplant cultivation under open field conditions. A total 75 kg/ha P_2O_5 and 60 kg/ha K_2O were applied during soil preparation, while 200 kg ha^1 N, 75 kg/ha P_2O_5 and 60 kg/ha K_2O were weekly and unformal fertigation with the irrigation system.

Measurements

Five (5) experimental plants were randomly selected from three (3) replications at 65 days after transplanting to measure the following characteristics: plant height (cm), number of branches on the plant, fruit length (cm), fruit diameter (cm), number of days to 50 % flowering, fruit weight (g), early yield (ton/fed) and total yield (ton/fed).

Statistical Analysis

Data were subjected to statistical analysis and mean of different accession were compared using the Duncan's multiple range test according to Snedecor (1973). [31]

Plant Height (cm)

Brinjal plant height is considered as one of the most significant characters for growth and development of the plant. The results in Table (2) indicated that there were significant differences among all studied genotypes in this trait in both studied seasons. The highest values of plant height were obtained from both genotypes strain Selection 3 and Black balady (91.41cm and 91.73cm) in both season 2018 and 2019 respectively. On the other hand, the lowest values for plant height were obtained from Black Beauty genotypes in both studied seasons under el-Kharj conditions. These results agree with earlier workers who reported genetic variability evaluated among some garden egg and pepper accessions (Kubie, 2013) [18] (Surya *et al*., 2013). [33] Rai *et al*. (2000) reported that the number of primary branches per plant is an important yield determining character in brinjal crop. Similar results also reported by Hossain *et al*. (2000), [11, 35] Mohanty (2001) [11, 21] and Thangamani (2003). In many researches, the phenotypic variation has reported in eggplant accessions.

Number of Branches per plant

Number of branches per plant character are presented also in Table 2. There are high significant differences in this trait in both studied seasons. The highest values of this character

were obtained from cultivar Black Beauty (13.97 and 14.38) in both studied seasons. While, both genotypes Strain Selection 3 and Florada Market 10 gives the lowest number of branches per plant in the first and second season respectively. Eggplant branch number per plant has been found correlated with endogenous hormonal level and apical dominance and also influenced by genetic makeup of the treatments. High variability for number of branches per plant was reported by Muniappan *et al*., (2010) [22] and Arunkumar *et al*., (2013). [2] Sulaiman *et al*. (2020) [32] stated that significant variations were recorded among the varieties for number of branches, plant height, stem diameter, and days to first flowering. Similar with other vegetative parameters, plant height contributed by genetic makeup was indirectly influenced by the environmental factor such as growing conditions. Naik *et al*. (2010) [23] also stated high genotypic and phenotypic variations among the different cultivars of brinjal.

Days to 50 % flowering

In respect of growing environments, the eggplant genotypes showed a significant variation for days required for flowering (Pandit *et al*., 2010). [28] They also stated that the days required for flowering in summer seasons was much longer compare to autumn-winter season. Although eggplant is basically a day neutral plant but many genotypes marked differences in prerequisite for days to required first flower in different seasons proved the plant is thermosensitiveness. It has been reported that high temperature during day and night not only favored the plant height but also kept the plant long vegetative phase. Data in Table (2) indicated that there were significant differences among these eggplant genotypes in this trait in both studied seasons, Both Selection 3 and black balady genotypes were earlier genotypes for flowering in 2018 and 2019 season respectively. While, Florada Market 10 genotype was the later flowering compared with other genotypes and gave the highest values for days to 50% flowering in both studied seasons. The onset flowering in brinjal was 40 days earlier in autumn-winter than the summer seasons (Negi *et al*. 1999). This might be positive effect of high temperature on prolong vegetative growth of brinjal plant.

Fruit length (cm)

Data in Table (2) show that, under the high temperature conditions of El-Kharj region the highest fruit length was obtained from eggplant genotype Florada Market 10 and gave (16.83 and 16.43cm) in the first and second seasons respectively. While, the lowest value of fruit length was obtained from eggplant genotypes selection 3 and Black Beauty in the both studied seasons respectively. Pandit *et al*. (2010) [28] observed that number of fruits and fruit length per plant differed among the eggplant genotypes and rainy-summer season recorded a smaller number of fruits compared to autumn-winter seasons. Mahanty and Prusti (2000) also reported similar results in case of brinjal plants. It was also stated that environmental factors produced a significant role in fruit weight and number of brinjal genotypes and low temperature stimulate flowering, fruit set and increased number of fruits.

Fruit diameter (cm)

The highest values for fruit diameter character was obtained from the eggplant genotype Black beauty and was significantly higher than other genotypes except selection3 in the second seasons (Table 2). On the other hand, the lowest values for fruit diameter was recorded by Florada Market 10 genotype and was significantly lower than other genotypes in both studied seasons. Fruit parameters like fruit length, fruit breadth fruit weight and fruit yield revealed a highly significant correlation with each other suggesting that increase or decrease in one parameter directly influences the increase or decrease in the other character. Chattopadhyay *et al*. (2011) made similar observation in a study of fruit weight and fruit breadth of eggplant. The yield of brinjal being polygenic trait, is a result of component chracters like fruit number per plant, fruit length, fruit diameter and fruit weight. Fruit yield and quality of brinjal depends on the genotypes, environmental conditions and the stage of harvested fruits. Genotypic coefficient of variation of a variety depends on the number of branches, inter nodal length, average fruit weight, number of fruits and fruit weight per plant (Inderesh, 1997). [13] Rahman (1999) [29, 35] and Uddin *et al*. (2014) [35] also reported that fruit weight, fruit length and days required 50% flowering were varied among the brinjal cultivars.

Fruit weight (g)

The results revealed that Florada Market 10 gave the highest values for fruit weight and was significantly higher than other eggplant genotypes in both seasons 2018 and 2019. Nevertheless, the less fruit weight was obtained from eggplant genotype Selection3 in both studied seasons under the El-Kharj conditions. Thuy (2002) and Uddin *et al*. [35] (2014) classified the diversity of eggplant based on morphological characters as high (H'=> 0.750), moderate (H'=0.50-0.75) and low (H'=<0.50) diversity. Given that morphological characters vary with the environment, uses of molecular markers such as simple sequence repeat (SSR) are advisable to identify polymorphism trait that is not influenced by the environment (Stachel *et al*., 2000).

Early yield (ton/fed)

Genetic variation in crop variety is very important for fruitful selection and crop improvement programs (Idahose *et al*., 2010). Both eggplant strain Selection 3 and Black Beauty gave the highest values of early yield under conditions of high temperatures in both growing seasons. Whereas, in both seasons the lowest values for early yield recorded in Florada Market 10 genotype. These findings suggest generally that the eggplant seedlings responded well by increasing water supply, since irrigation each two days gave the highest values of these traits. In this deference, Aujla *et al*. (2007) observed that the highest yield of eggplant under drip irrigation system was obtained under 75% Evapotranspiration (level of water loss) of the required water to irrigate eggplant plants. Yield among the brinjal genotypes varied significantly according to the growing season (Pandit *et al*.,2010). [28] They also stated that fruit yield significantly reduced in rainy-summer season due to higher temperature. Low fruit set due to higher temperature is the main cause for severe lowering in fruit set (Kalloo, 1990; Kumar *et al*., 2000). The low yield of brinjal in rainy-summer season might be due to reduced fruit size and lighter fruit weight. Therefore, the yield of brinjal depends on genotypes as well as environmental conditions. Similar findings were reported by Devi and Sankar (1990), [9] Vadivel and Babu (1990). [36]

Total yield (ton/fed)

There were significant differences among the tested eggplant genotypes for total yield character Table (2). The results showed that, Black Beauty gave the highest values and was significantly higher than other eggplant genotypes. Also, the lowest values of total yield were obtained from Florada Market 10 genotype and was significantly lower than other genotypes in both studied seasons. Higher fruit yield per plant was attributed to the factors that they showed higher fruit girth, fruit weight and number of fruits per plant. The results are in concordance with those of Prabhu *et al*., (2008) [27] and Dharwad *et al*., (2009). [10] Fruit yield is complex character and determined by poly genes which is highly influenced by environmental and growing conditions. The genotypes differences always play a significant role in the yield determination. In this study, yield per plant and yield per hectare showed significant difference among the different genotypes of eggplant. The yield of eggplant is a polygenic character which is regulated by many yield contributing characters like fruit number, fruit weight and fruit length.

Table 2: Evaluated five eggplant genotypes during 2018 and 2019 seasons at AL-Kharj, Alhayatem, Saudi Arabia conditions.

Genotypes	Plant height (cm)		Number of branches/plants		Days to 50% Flowering		Fruit length (cm)		Fruit Diameter (cm)		Fruit Weight (g)		Early yield (ton/fed)		Total yield (ton/fed)	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Balady black	89.78 AB	91.73 A	12.58 B	12.69 B	61.62 B	60.37 C	14.31 B	13.18 B	8.170 C	7.790 C	154.7 C	151.3 C	6.767 C	6.543 C	15.67 C	14.20 D
Black Beauty	82.92 D	86.79 C	13.97 A	14.38 A	61.12 B	61.10B C	11.40 C	11.40 C	11.017 A	9.570 A	176.6 B	179.1 B	9.000 A	8.700 A	26.33 A	23.25 A
Florada Market 10	87.69BC	87.46 BC	11.35 C	11.91 B	63.61 A	63.59 A	16.83 A	16.43 A	6.707 D	6.093 D	229.1 A	230.6 A	7.110 C	6.960B C	14.06 D	13.80 D
Selection 2	84.42 CD	88.18B C	9.33 D	12.11 B	60.08 B	60.67 BC	11.35 C	12.83 B	8.093 C	8.307 B	146.4 CD	153.1 C	7.873 B	7.540 B	16.08 C	16.28 C
Selection 3	91.41 A	90.43 AB	8.55 E	12.31 B	60.74 B	61.74 B	11.17 C	11.52 C	9.330 B	9.533 A	140.8 D	142.4 D	9.340 A	9.157 A	20.48 B	19.63 B

Means followed by the same letter, within the same column, do not significantly different at 0.05 level of probability.

Conclusion

From this study, it is concluded that all these five genotypes of eggplant differed significantly for most vegetative and reproductive characters. The heritability value for all genotype was the highest for all the vegetative and reproductive characters, signifying that the foremost part of the variability was due to genotypic reasons. The genotype Black Beauty showed the lowest plant height, highest number of branch and the highest yield than other eggplant genotypes.

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