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MORPHOLOGICAL, PHYSIOLOGICAL AND BIOCHEMICAL RESPONSES OF EGGPLANT (*Solanum melongena* L.) SEEDLING TO HEAT STRESS

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High temperature stress under changing climatic conditions affects the eggplant like other vegetables. However, heat tolerant local germplasm of eggplant has not been identified currently. Hence, a brief research investigation was carried out to assess the heat tolerance potential of eggplant genotypes at seedling stage. The experiment was conducted under Completely Randomized Design (CRD), having four replications. One month old seedlings of four genotypes of eggplant (25919, Nirala, 28389 and Pak-10927) were subjected to high temperature, (45ºC/35ºC day/night) for a period of seven days. Heat stress tolerance ability of selected genotypes was evaluated by measuring the morphological (number of leaves/plant, leaf area, root shoot lengths, plant biomass), physiological (photosynthetic rate, stomatal conductance, rate of transpiration, water use efficiency, chlorophyll contents) and biochemical (Superoxide dismutase, Peroxidase, Catalase) characteristics. Genotypes exhibited considerably diverse behaviour at high temperature. Genotypes (25919 and Nirala) showed heat tolerance in all recorded variables, while genotypes (28389 and Pak-10927) were susceptible towards heat stress. So, it can be deduced from the findings that genotype 25919 is heat tolerant genotype and may be incorporated in vegetable breeding program in order to produce a heat tolerant variety having great potential to cope with adverse impact of elevated temperature stress. However, Pak-10927 genotype was found most heat sensitive among the studied genotypes.
Keywords: Eggplant, heat stress, genotypes, morphological, gaseous exchange, biochemical.

INTRODUCTION

Vegetables are very important due to their considerable nutritional value (Shaheen *et al*., 2013) but most of the vegetable crops are known for their high sensitivity to salt and heat stress (Shaheen *et al*., 2013). Eggplant (*Solanum melongena* L.); the so-called aubergine, guinea squash or brinjal (Kantharajah and Golegaonkar, 2004) is a vegetable of significant importance around the globe having high nutritive value and a good source of dietary fibers, minerals and vitamins (Obho *et al.*, 2005; Abbas *et al*., 2010). Eggplant is an important summer vegetable of Pakistan exposed to high temperature stress, during hottest months (May-July) (HKO Report, 2012). Eggplant peel is rich in a constitutive composite known as anthocyanin and technically called nasunin: a possible counter oxidative agent with its functions in eradicating radicals, thus providing defense to brain membranous cells (Sadilova *et al*., 2006; Das *et al*., 2015; Jing *et al*., 2015).
Different plant species have a temperature range to perform in an optimum manner as depicted from the range of 30-35ºC with some variations (Prasad *et al*., 2008; Hussain *et al*., 2018; Qadir *et al*., 2019; Shafqat *et al*., 2019). About 10-15% crop damages have been reported with each 1ºC temperature rise during various phases of plant growth and development (Upadhyaya *et al*., 2011). Similar kind of research has shown a crop loss of 17% in the reports of Hayat *et al*. (2009). Any variation in temperature, high or low, can influence the plant emergence, maintenance along with growth characteristics. Kumar *et al*. (2011) reported that plant growth inhibition under high temperature stress depends on temperature elevation (degrees), duration of treatment and genotype. High temperature is causing many problems with a distinguished yield loss and must be managed in an effective way. Most of the plants have internal mechanism making them capable to devoid themselves against more damages (Hasanuzzaman *et al*., 2013). Tomato is an important vegetable crop sensitive to heat stress as documented by (Shaheen *et al.*, 2013; Araiz *et al*., 2017).
Eggplants are cultivated, both in tunnels and open farms as well (Ion and Victor, 2013). Their germination and growth differed incredibly with selected site and input supplies. Along with biotic stresses many abiotic stresses also affect the crop of eggplant as was reported by Mustafa *et al*. (2016). Ordinarily spring crop is taken for more observations and is taken by the agriculturists to satisfy the market requests with people needs (Wang *et al*., 2014). Growth and yield parameters of eggplants affected by both biotic and abiotic factors (Molua and Lambi, 2006; Wang *et al*., 2014). Kaizi and Chen (2005) evaluated the potential of heat stress tolerance in 14 eggplant cultivars at seedling stage. They found increased electrolyte leakage and raised proline

contents in response to heat stress. Radical growth was severely affected by heat stress in eggplant at seedling stage (Sakera *et al*., 2012). Moreover, (Li *et al*., 2011) reported the optimal temperature for eggplant species fall between the ranges of 22-30 ºC. Furthermore, different varieties of eggplant probable to have diverse optimum temperature range as suggested by some other researchers (Minghua *et al*., 2001; Li and Yu, 2004). The temperature increases instantly after the end of February month. The raised temperature is the essential limitation making the yield just in early season of the crop (Bita and Gerats, 2013; Lesk *et al*., 2016). Along these lines, an extremely shorter time traverse and developing season is there to consolidate a good yield (Abbas *et al*., 2010). The fundamental deterrent factor as specified before is the stress induced by high temperature (Alam *et al*., 2011). The regions of central Punjab and southern Punjab are practically at the edge of even heat strokes alongside progressive advances in late spring (Aslam *et al*., 2017). In this manner, the proficient yield improvement is recently turning into a huge assignment to accomplish (Goraya and Asthir, 2016; Aslam *et al*., 2017). Elevated temperature stress has damaging impact on vegetable crops (Tiwari, 2011). Due to considerable relations of high temperature and eggplant growth attributes and availability of only few documented reports on eggplant response to heat stress in Pakistan, the present research was carried out to explore heat tolerance potential in eggplant genotypes.

MATERIALS AND METHODS

***Site of experimentation*:** The current research investigation was performed during 2017-18 in growth room of stress physiology lab, Institute of Horticultural Sciences, UAF. Four eggplant genotypes namely 25919, Nirala, 28389 and Pak-1097 were assessed for their genetic potential against heat stress collected from Plant Genetic Resource Institute, Islamabad and Vegetable Research Institute, Faisalabad.

***Procedural details*:** Healthy, uniform sized viable seeds of pre-selected eggplant genotypes were grown in medium sized plastic containers comprising sterilized sand as a growing media. Germination started after about a week of sowing depending upon genotype. Thinning operation was done in order to maintain number of plants per replication on appearance of first true leaf on the seedlings. Irrigational and nutritional requirements of the plants were fulfilled by application of distilled water and half strength Hoagland and Arnon (1950) nutrition composition, respectively throughout experimentation. After keeping in optimum temperature for one month, plants were subjected to high temperature (45/35ºC) that was given by steady increasing the temperature to evade osmotic and heat shocks. Two degree centigrade temperature was raised every day until the desired high temperature (45/35ºC) was obtained. Initially the growth room temperature was kept on 27ºC which is considered to be optimal for proper eggplant growth. One pot was taken as one replication (five plants per replication) and four pots per genotype were considered. Data was recorded after on seventh day of heat exposure.

***Number of leaves per plant*:** Leaves are important indicator of plant's growth because photosynthetic activity of the plant occurs in leaves. The numbers of leaves of eggplant genotypes were counted and average was noted for each replication.

***Leaf Area (cm^2)*:** Leaves were carefully selected from all repetitions and detached from parent plant. The selected uniform sized leaves were properly spread on base of a digital meter (LI-3100; LI-COR, Inc., Lincoln, Nebr.) for the measurement of leaf area (cm^2). Mean area/ leaf was estimated according to procedure devised by Micheal *et al*. (2002).

***Shoot length (cm)*:** Data regarding length of eggplant shoots was noted on the termination of study by using a counting scale (cm), right from the basal point of plant to the apex of plant and mean were taken and computed for all replicates.

***Root length (cm)*:** After recording data regarding all non-destructive variables, plants were uprooted in the last and roots were carefully washed with tap water. Roots were dried carefully to avoid any damage and length was recorded by scale in centimetres from shoot base to root apex and mean value for all repeats was calculated.

***Plant biomass (g)*:** Five seedlings from each replicate were selected at random, carefully stored in brown paper bags to place in oven (Memmert-110, Schawabach, Germany) and desiccated for 72 hours at 70°C temperature. The dry matter contents were computed by using highly precise digital weighing balance and mean dry matter of each repeat was calculated.

***Photosynthesis rate (µmol m^{-2}s^{-1}), stomatal conductance (mmol m^{-2} s^{-1}) and transpirational rate (mmol m^{-2}s^{-1}*:** Measurements were made regarding leaf gaseous exchange variables, i.e. rate of photosynthetic activity, transpirational rate and stomatal conductance. The variables were recorded as heat stress has direct or indirect negative impact on the variables mentioned above. Three young, healthy and fully developed leaves from plant (two plants from every replicate/treatment) were chosen. Those leaves after careful cleaning were kept one after another in the square cavity of Infra-Red Gas Analyzer (IRGA), (LCi- SD, ADC Bio-scientific UK) (Zekri, 1991; Moya *et al*., 2003). Every measurement of aforementioned gas exchange related variables were made at same time with specific prevailing conditions, such as 403.3 mmolm$^-$s$^-$ molar air flow per unit leaf area, water vapours compression into square cavity ranged from 6 to 8.9 mbar, up to 1711pmolm$^-$s$^-$ was PAR at leaf surface, atmospheric pressure of 99.9 kPa, chamber temperature extended from 22.5 to 27.8°C and chamber Carbon dioxide absorption was 352pmol mol^{-1}.

***Water use efficiency (µmol CO_2mmol^{-1} H_2O)*:** It is the proportion of photosynthesis process (Pn) to volume of water loss during transpiration (E) that was computed by using the formula as described by (Medrano *et al*., 2015):

$$\text{Water use efficiency (WUE)} = \frac{\text{Rate of photosynthesis (Pn)}}{\text{Rate of transpiration (E)}}$$

***Chlorophyll contents (SPAD value)*:** Quantity of chlorophyll produced was estimated by measuring the total chlorophyll contents in leaves with a digital chlorophyll meter (CCM-200 plus Bio-Scientific USA).

Super oxide dismutase (SOD) activity (mg g^{-1} FW): The antioxidant activity of super oxide dismutase enzyme was found by recording the capability to hinder the NBT (nitrobluetetrazolium) photo reduction by applying the methodology given by (Giannopolitis and Ries,1977; Wu *et al*., 2010). In order to estimate the SOD activity, reaction composition comprising test tubes were placed underneath ultra violet lamp for a period of fifteen minutes and addition of riboflavin was made into it, the absorbance at 560 nm was recorded afterwards. One single division of dismutase activity was distinguished as "that volume of the enzyme subdued fifty percent photoreduction of nitrobluetetrazolium".

***Activities of peroxidase and catalase (POD & CAT) (mg g^{-1} FW)*:** Measurement of peroxidase enzyme and catalase enzyme activities was made by using the methodology described by Chance and Maehly (1995) with few amendments. The response mixture for peroxidase enzyme comprised of 50 mM phosphate buffer with 5pH, 40 mM hydrogen peroxide (H_2O_2), 20 mM of guaiacol, and 0.1 mille liters of resin mixture. At each 20 second interval, change in absorbance of the response blend at 470 nm was measured. One single unit of peroxidase enzyme was described for example "an absorbance alteration of 0.01 units/ minute". The response mixture for measuring activity of catalase enzyme comprised of 50 mM phosphate buffer with 7 solution pH, 5.9 mM hydrogen peroxide (H_2O_2), and 0.1 mille liters of resin solution. Addition of the sample was the initiation point of the reaction. After each 20 seconds, variations in absorbance of the response mixture at 240 nm were noted with great care. One single unit of catalase enzyme was termed as "absorbance variation of 0.01 units/ minute".

***Experimental layout and statistical analysis*:** The trial was carried out conferring to Complete Randomized Design. Recorded observations were analysed statistically by following Fisher's technique of Variance Analysis (ANOVA) and significant differences among the mean values of genotypes were assessed by using Highest Significant Difference test (Tukey's test). The whole analysis was performed by using software Statistix 8.1.

RESULTS

***Number of leaves per plant*:** The genotype 25919 produced the highest per plant number of leaves (6) followed by Nirala (5.25). The minimum (3) number of leaves per plant were noted in genotype 28389 followed by pak-109279 (2.5). (Fig.1a). Highly significant ($P \leq 0.01$) results were obtained concerning this growth variable. The collected data regarding leaf number indicated that genotype 25919 had more capability to endure heat stress effects and produced higher number of leaves in comparison to Pak-10927. The tabulated data (Means ± SE) regarding per plant number of leaves under heat stress is portrayed in Table 1.

***Leaf area*:** The genotype 25919 represented the highest leaf area next to that Nirala genotype came with the value (4.7 cm^2) for leaf area. The minimum leaf area (3.17 cm^2) was recorded in genotype 28389, followed by pak-10927 (2.52 cm^2) at 45°C temperature (Fig.1b). Significant ($P \leq 0.05$) results were established concerning leaf area of selected eggplant genotypes. The detailed data (Means ± SE) regarding leaf area in genotypes under high temperature is presented in Table 1.

***Shoot length*:** The genotype 25919 possessed the maximum values concerning shoot length (18.42 cm) followed by Nirala. However, at 45°C, the minimum values about shoot length were experienced in genotypes Pak-10927 (8.07cm) and 28389 (9.12cm) (Fig.1c). Highly significant results ($P \leq 0.01$) were recorded regarding shoot length of eggplant seedlings. The detailed data (Means ± SE) regarding shoot length of genotypes under heat stress is portrayed in Table 1.

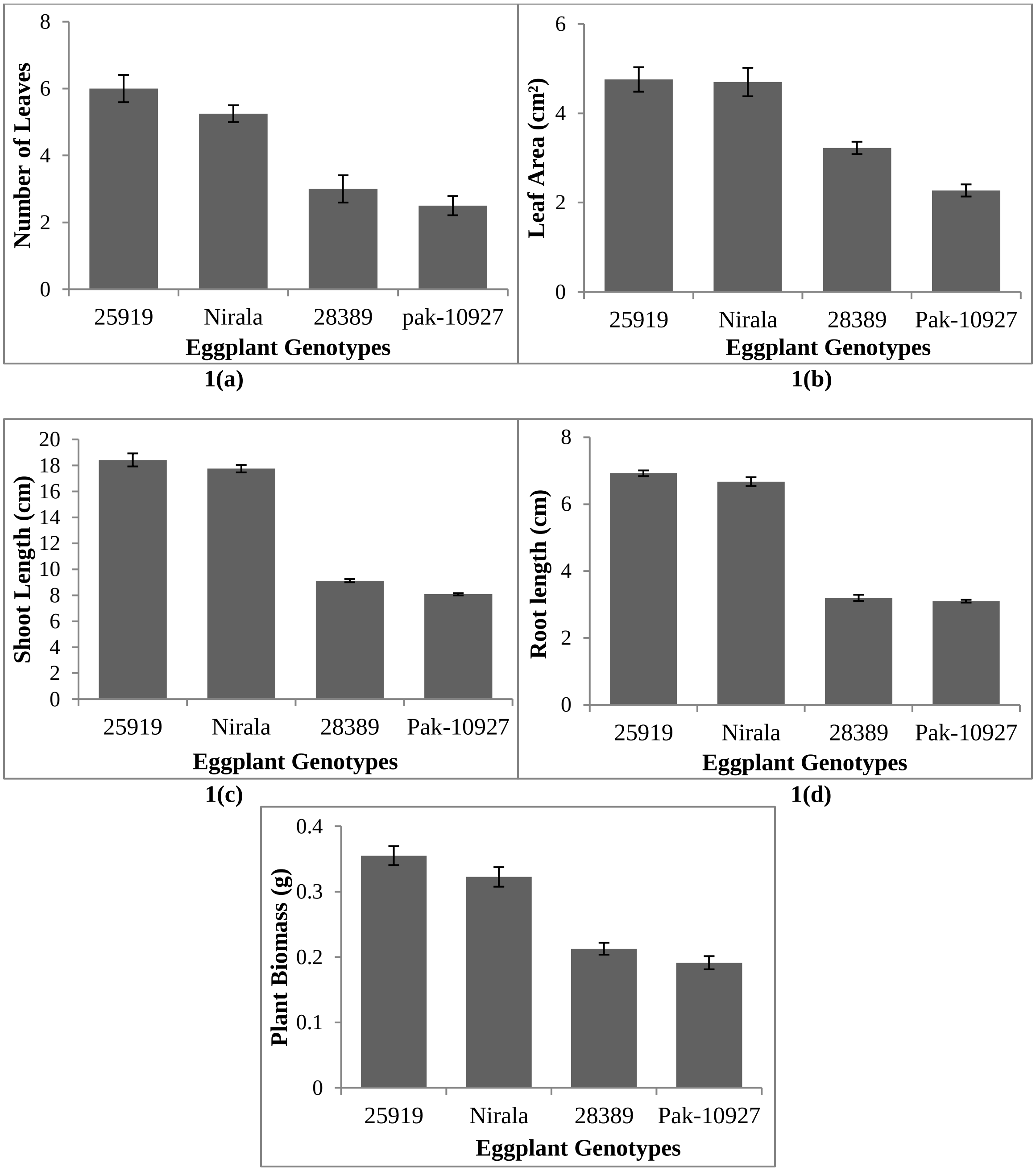
***Root length*:** The genotype 25919 gave the highest root length (6.92 cm), followed by Nirala (6.67 cm) which performed as second best genotype on this ground. The lowest root length was observed in 28389 (3.2 cm) statistically at par to that of Pak-10927(Fig.1d). Highly significant results ($P \leq 0.01$) concerning root length of eggplant seedlings were observed at 45°C.The detailed data (Means ± SE) concerning root length of genotypes under heat stress is portrayed in Table 1.

***Plant biomass*:** The recorded data showed that the genotype 25919 exhibited 0.35 g plant biomass and Nirala produced 0.3g dry matter (Fig.1e). The lowest plant biomass was

Table 1. Comparison of morphological traits of eggplant genotypes at 45°C temperature.

Genotypes	Number of leaves	Leaf area (cm^2)	Shoot length (cm)	Root length (cm)	Plant biomass (g)
25919	4.75 ± 0.27 a	6.00 ± 0.40 a	18.42 ± 0.50 a	6.92 ± 0.064 a	0.355 ± 0.064
Nirala	4.70 ± 0.31 a	5.25 ± 0.25 a	17.75 ± 0.29 a	6.66 ± 0.040 a	0.322 ± 0.040
28389	3.22 ± 0.13 b	3.0 ± 0.40 b	9.12 ± 0.12 b	3.20 ± 0.050 b	0.212 ± 0.050
Pak-10927	2.27 ± 0.13 b	2.5 ± 0.28 b	8.07 ± 0.08 b	3.10 ± 0.250 b	0.191 ± 0.250

NL=Number of leaves, LA=Leaf area, SL=Shoot length, RL=Root length, PB= Plant biomass

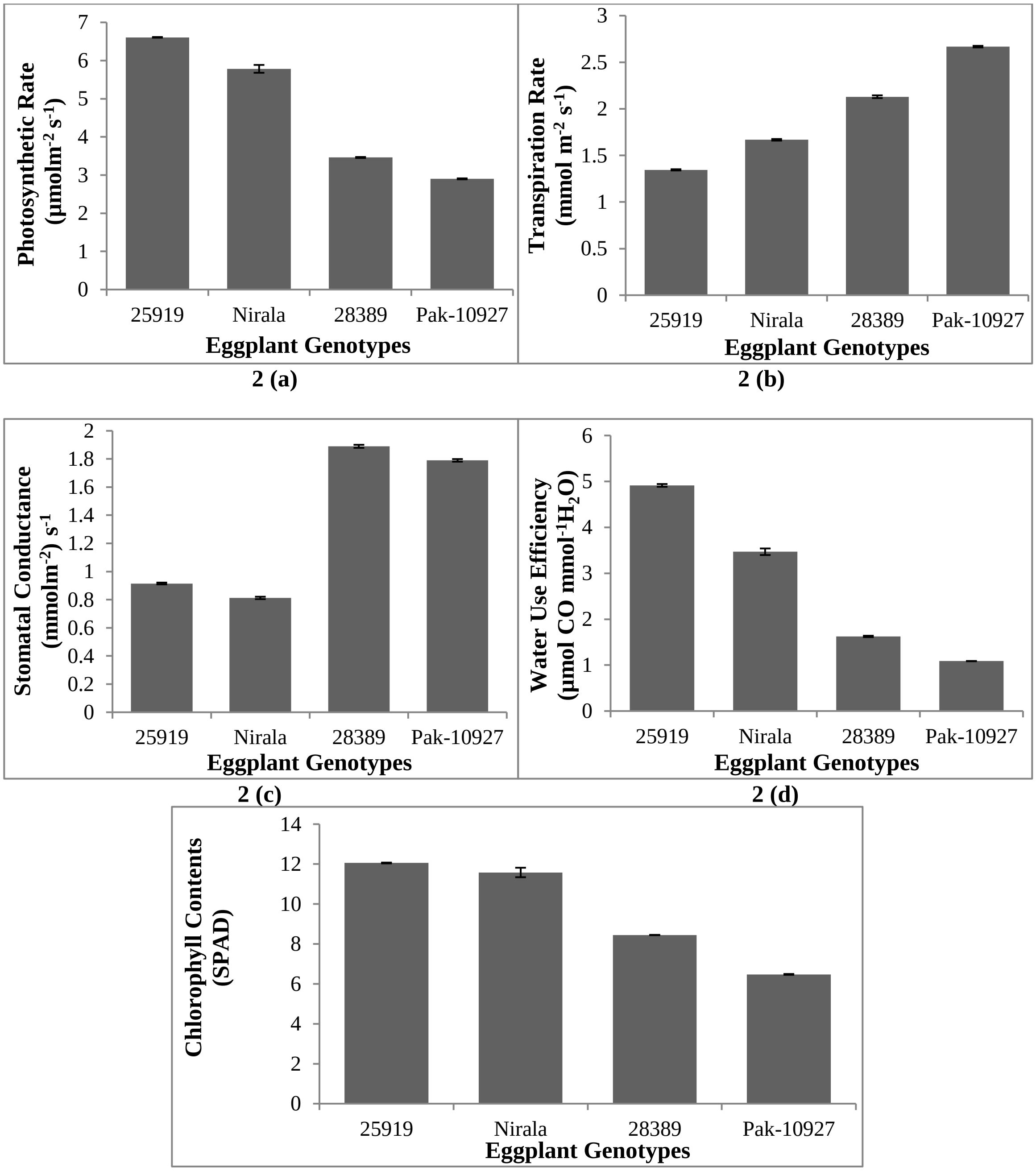


1(e)

Figure 1.(a,b,c,d,e): Variation in morphological characteristics of eggplant genotypes at 45°C temperature.

observed in Pak-10927 (0.19 g) and genotype 28389 possessed 0.21g of seedling dry matter content. Plant biomass was markedly reduced in genotypes 28389 and pak-10927 under prevailing conditions of heat stress (Table 1). Significant results (P≤0.05) concerning plant biomass of eggplant seedlings were observed.

Gaseous exchange related attributes: Figure 2a reveals that highly significant (P≤0.01) results were observed related to leaf photosynthesis rate in eggplant genotypes at seedling stage after exposure to heat stress. The genotype 25919 was found best performing photosynthesis process under stress by exhibiting 6.60 µmol $m^{-2}s^{-1}$ photosynthesis ratio, after that Nirala genotype who gave 5.78µmol $m^{-2}s^{-1}$photosynthetic ratio which ensures their survival under high temperature regimes. The minimum rate of food making process (photosynthesis) was measured in genotypes pak-10927 and



2 (e)

Figure 2.(a,b,c,d : Variation in Gas exchange characteristics of Eggplant genotypes at 45°C temperature.

28389, (3.46µmol m^{-2}s^{-1}, 2.9µmol m^{-2}s^{-1}) both of the genotypes were considered as heat sensitive genotypes. The results showed that transpiration increased in sensitive genotypes. The genotype 25919 gave the minimum value (1.34mmol m^{-2}s^{-1}) for rate of transpiration.

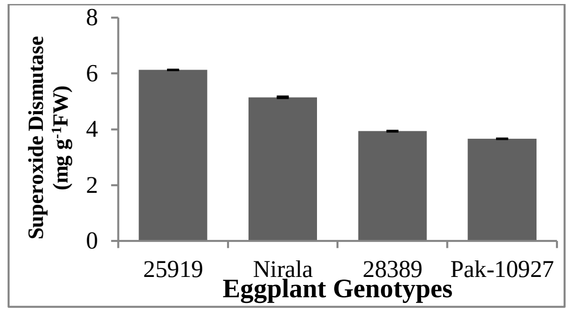
The genotype pak-10927 gave the maximum value (2.66mmol m^{-2}s^{-1}) for ratio of transpiration. Significant results were recorded for leaf transpiration ratio of eggplant seedlings. The measurements made at the end of the experiment showed that the genotypes differed in a significant manner ($P \leq 0.05$) in their reaction about stomatal conductance under elevated temperature regime. The genotype Nirala exhibited the least (0.812mmol m^{-2} s^{-1}) stomatal conductance, followed by 25919 (0.915mmol m^{-2} s^{-1}), whereas, the peak value for this variable was noted in genotype 28389 (1.89mmol m^{-2} s^{-1}), after that genotype pak-10927 (1.79mmol

m^{-2} s^{-1}) (Fig. 2c). Outcomes of significantly diverse behavior were established regarding stomatal conductance of eggplant seedlings at temperature stress of 45ºC. The genotype 25919 was found best on this ground by possessing maximum value (4.91µmol CO_2mmol^{-1} H_2O) for water use efficiency, followed by Nirala (3.46µmol CO_2mmol^{-1}H_2O) which may be considered a heat tolerant genotype (Fig.2d). The minimum efficiency of water use was noticed in pak-10927 and was at par with 28389 at 45ºC. Results of high significance were found regarding water use efficiency of eggplant seedlings. The detailed data (Means ± SE) concerning gaseous exchange related attributes of genotypes at 45ºC is accumulated in Table 2. The graphical presentation of data regarding gaseous exchange related attributes is depicted in Figure 2a, b, c, d.

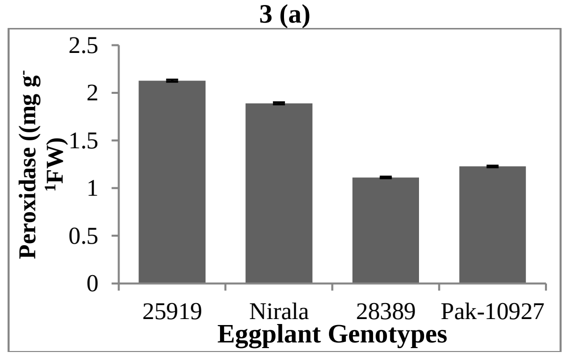
***Chlorophyll contents*:** Maximum values for chlorophyll contents were found in leaves of eggplant genotypes 25919 (12.5) and Nirala (11.58) (Fig. 2e). However, genotypes 28389 and Pak-10927 were lower in production of chlorophyll at 45ºC. Genotype pak-10927 showed lower (6.47 SPAD value) chlorophyll contents as compared to genotype 28389 (8.44 SPAD value) (Fig. 2e). Highly significant response ($P \leq 0.01$) concerning amount of chlorophyll contents was noted in leaves of eggplant genotypes under high temperature of 45ºC. The elaborated data (Means ± SE) related to chlorophyll content is given in Table 2.

***Antioxidant activity of superoxide dismutase enzyme*:** The genotype 25919 exhibited the utmost (6.12 mg g^{-1} FW) antioxidant activity of superoxide dismutase enzyme, followed by Nirala (5.14 mg g^{-1} FW) (Fig. 3a). The least activity of superoxide dismutase enzyme was observed in genotype 28389 (3.66 mg g^{-1}FW). Significantly ($P \leq 0.05$) different values were observed about antioxidant activity of superoxide dismutase enzyme of eggplant genotypes. The elaborated data (Means ± SE) related to SOD activity is given in Table 3.

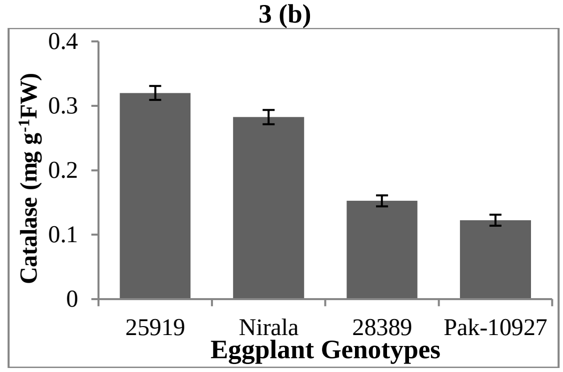
***Antioxidant activity of peroxidase enzyme*:** Highly significant ($P \leq 0.01$) values were found regarding antioxidant activity of peroxidase enzyme at 45ºC temperature in eggplant seedlings. The antioxidant activity of peroxidase enzyme was found highest (2.12 mg g^{-1} FW) in genotype 25919 followed by Nirala (1.89 mg g^{-1} FW) and recorded lowest (1.1 mg g^{-1} FW) in genotype 28389 (Fig. 3b). The results revealed that free radical scavenging activity by peroxidase enzyme was relatively more in genotypes 25919 and Nirala than those of 28389 and Pak-10927.



3 (a)



3 (b)



3(c)

Figure 3. (a,b,c): Variation in biochemical characteristics eggplant genotypes at 45ºC temperature.

Table 2. Comparison of gaseous exchange related traits of eggplant genotypes at 45ºC temperature.

Genotypes	Photosynthetic rate (µmol $m^{-2}s^{-1}$)	Transpiration rate (mmol $m^{-2}s^{-1}$)	Stomatal conductance (mmol m^{-2} s^{-1})	Water use efficiency (µmol CO_2mmol^{-1} H_2O)	CC (SPAD value)
25919	0.0230 ± 0.0095 a	1.34 ± 0.0091 a	0.910 ± 0.0070 a	0.430 ± 0.051 a	12.55 ± 0.08 a
Nirala	0.0200 ± 0.0085 a	1.66 ± 0.0110 b	0.812 ± 0.0063 b	0.855 ± 0.038 a	11.58 ± 0.28 a
28389	0.0020 ± 0.0070 b	2.13 ± 0.0165 c	1.890 ± 0.0130 c	0.240 ± 0.011 b	8.44 ± 0.04 b
Pak-10927	0.0017 ± 0.0085 b	2.66 ± 0.0064 d	1.790 ± 0.0300 d	30.88 ± 0.014 c	6.47 ± 0.06 c

PR=Photosynthetic rate, TR=Transpiration rate, SC=Stomatal conductance, WUE=Water use efficiency, CC=Chlorophyll contents

Table 3. Comparison of biochemical traits of eggplant genotypes at 45ºC temperature.

Genotypes	Superoxide dismutase (mg g^{-1} FW)	Peroxidase (mg g^{-1} FW)	Catalase (mg g^{-1} FW)
25919	6.120 ± 0.063 a	2.12 ± 0.0017 a	0.330 ± 0.0064 a
Nirala	5.140 ± 0.059 b	1.89 ± 0.0000 b	0.280 ± 0.0043 a
28389	3.930 ± 0.024 c	1.11 ± 0.0016 c	0.155 ± 0.0064 b
Pak-10927	0.003 ± 0.031 d	1.22 ± 0.0012 d	0.122 ± 0.0047 b

SOD= Superoxide dismutase, POD=Peroxidase, CAT=Catalase

The details of numerical data (Means ± SE) concerning antioxidant activity of POD enzyme in all genotypes under heat stress is portrayed in Table 3.

***Antioxidant activity of catalase enzyme*:** The antioxidant activity of catalase enhanced with the onset of heat stress. The heat tolerant genotype 25919 showed maximum (0.32mg g^{-1} FW) catalase antioxidant activity, after that Nirala (0.28mg g^{-1} FW). The lowest antioxidant activity of catalase enzyme was observed in pak-10927 (0.12mg g^{-1} FW) (Fig. 3c). Highly significant ($P \leq 0.01$) response was found regarding antioxidant activity of catalase in eggplant seedlings. The detailed numerical data (Means ± SE) concerning antioxidant activity of CAT enzyme in all genotypes under heat stress is portrayed in Table 3.

DISCUSSION

High temperature (HT) stress is among the major environmental factors that restricts plant's growth, development and ultimately plant productivity globally (Hasanuzzaman *et al*., 2013) making the plant scientists concerned to deeply study the damages occurring in response to heat stress. The current investigation explores the thermo-tolerance potential of eggplant genotypes when treated with high temperature (45˚C) It provides a clear picture that different eggplant genotypes performed differently physiologically and bio-chemically under high temperature stress. Abdelmageed *et al*. (2009) and Uddin *et al*. (2014) reported that different eggplant genotypes showed variable thermo tolerance to high temperature stress as was found in this study. Genotype 25919 showed reasonable growth under heat stress (45˚C) than other genotypes as was reported by early worker (Naika *et al*., 2005), indicating that the genotype is more heat tolerant (Uddin *et al*., 2014).

Results regarding vegetative parameters such as number of leaves per plant, leaf area, shoot & root lengths and plant dry matter of genotypes evaluated in present experimentation described the varied behaviour of genotypes under heat stress. Similar kind of results were also reported earlier by (Hussain *et al*., 2016) who worked on Okra under heat stress. The results stipulate that the genotype that has been able to possess more number of leaves at high temperature (45˚C) might have potential to exhibit more growth as compared to genotypes with relatively less number of leaves. The genotype with more leaves possessed relatively better growth. The varied behaviour about this growth characteristic is supported by other findings of earlier investigations (Hussain *et al*., 2007). As for as leaf area is concerned the genotypes possessed higher values on this ground also showed maximum photosynthetic activity. The probable reason for this may be the greater leaf surface area is able to capture maximum light required for photosynthesis as was described by many researchers (Hussain *et al*., 2016). Roots help the plants under stressful conditions by growing deeper into the soil and making possible a better uptake of water and nutrients to avoid desiccation of plant tissues (Wahid *et al*., 2007). In current study the genotype exhibit maximum root length showed maximum shoot growth and plant dry matter contents as well which might be due to improved avoidance mechanism of the genotype as many studies support the results (Wahid *et al*., 2007).

In addition to vegetative traits, significant difference was also observed in gaseous exchange parameters. A number of studies have been published describing heat stress effects on photosynthesis process (Goraya *et al*., 2017). The stress induced variations in leaf photosynthetic rate depend on exposure duration, intensity and recovery mechanism commencement during stress factors. Photosystem II normally provides the standpoint for mechanism of photosynthesis system (Adir *et al*., 2003; Murata *et al*., 2007). The diversity in genotypes evaluated during this study, regarding gaseous exchange parameters at high temperature (45ºC) is also supported by (Hussain *et al*., 2016). Maximum rate for photosynthetic activity was also showed by the genotype 25919 and exhibited minimum transpiration rate. Relatively higher transpiration rate was seen in genotype pak-10927 which also found less efficient in using available water showing least water use efficiency (WUE). A number of similar studies were also reported in a review (Wahid *et al*., 2007). Heat stress boosts up the transpiration process because water molecules get energy to flee from leaf surface so rapid plant surface water loss lead to dehydration of the organ (Mazorra *et al*., 2002). Relatively higher values regarding transpiration were noted at 45ºC temperature in genotypes of eggplant and this may be the reason of tissue desiccation and wilting and drying of leaves. Review report of (Wahid *et al.*, 2007) confirms our results about transpiration rate. During current research investigation, leaves of eggplant genotypes (25919, Nirala, 28389 and Pak-10927) exhibited a varied range of chlorophyll content (SPAD value) at 45ºC temperature of growth chamber. Variation in chlorophyll production might be due to modifications in microscopic structures of plants in response to heat and this is also genotype dependent attribute (Semenova, 2004; Kreslavski *et al*., 2008). The genotype 25919 exhibited maximum chlorophyll contents among all the four evaluated accessions. Likewise, many research studies supported the current results (Shaheen *et al*., 2013; Hussain *et al*., 2016). The observed higher values for chlorophyll contents in leaves proved greater photosynthesis ability genotypes. The genotypes exhibited maximum chlorophyll contents also showed maximum photosynthetic activity under heat stress. Our present results regarding chlorophyll contents are supported by previously documented reports (Guilioni *et al*., 2003; Wang *et al*., 2009) who documented a rapid decrement in chlorophyll contents (chlorophyll a &b) and degree of the divergence depends on the heat tolerance capacity of plant species. Decrement in chlorophyll content (SPAD value) was also described by Shen *et al*., 2017 in Rhododendron spp. The study also strengthened the results of current investigation. Balouchi (2010), Reda and Mandoura (2011) also documented that plants subjected to heat stress exhibited less chlorophyll biosynthesis. The genotype 25919 exhibited maximum value for chlorophyll contents and gas exchange attributes describing that it is relatively heat tolerant genotype among the others at high temperature stress (Uddin *et al*., 2014).

Enhanced activities of enzymes; SOD, POD and CAT at 45ºC were observed in seedlings of eggplant genotypes (25919, Nirala, 28389 and Pak-10927) during current investigation. The genotype performed better in growth and physiological attributes also showed maximum values for antioxidant activities of enzymes making them more heat tolerant. The highest free radical scavenging activity was of superoxide dismutase was found in genotype 25919 indicating the genotypes is more heat tolerant. It is earlier reported that heat tolerant genotypes showed enzymatic antioxidants mechanisms more proficiently than the genotypes of susceptible nature (Wahid *et al*., 2007; Wahid *et al*., 2012). Enhanced activities of superoxide dismutase, peroxidase and catalase in tolerant genotypes were also reported by (Shaheen *et al*., 2013; Mustafa *et al*., 2017) under heat and salt stress. A resilient relationship was observed between activities of antioxidant enzymes and heat stress tolerance in present investigation. Our results were also confirmed by Chakraborty *et al.* (2011). Similar research findings were also reported in gerbera plants when heat tolerant varieties exhibited significantly higher protein, antioxidants and proline contents than the sensitive ones under elevated temperature regimes (Kim *et al*., 2016). The antioxidant activities of these enzymes varied based on tolerance of different plant species, growth phase and planting season (Almeselmani *et al*., 2006; Chakraborty *et al.,* 2011).

***Conclusion*:** It may be deduce from the study that the genotypes which represents more gas exchange components, activates their defences system and maintain their growth under high temperature stress are considered to be the heat tolerant genotypes. These genotypes may be used in further breeding program and for further recommendations under changing climatic conditions.

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