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RESEARCH PAPER

Screening of local and exotic germplasms of chilli (*Capsicum annum*) for drought tolerance

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Key Message: This study reveals the performance of two chilli varieties under drought conditions where exotic variety Bonanza gave good yield and quality attribute as compared to local Tatapuri variety under drought stress conditions.

Abstract: Drought is one of the major threats of the arid region of Pakistan. Drought stress affects the yield of chilli with up to 50% reduction. In view of this problem, a study was conducted to explore the drought resistance of a local variety Tatapuri (V_1) and an exotic variety Bonanza (V_2). Pot experiment was conducted with three treatments T_0 control (well-watered), T_1 (75 % stress), T_2 (50 % stress) and T_3 (25 % stress) at vegetative and reproductive stages by three replications. In general a negative relationship was found for all of the variables measured aside from proline substance. The variety V_2 took more days to 50 % blooming, having superior plant height, fruit length, width and weight, numbers of fruit per plant, number of seeds per fruit, proline substance, ascorbic acid and chlorophyll content. V_1 had excessive number of branches/plant in T_0. Results of the studied parameters revealed the significant impact of the treatments on chillies cultivars under drought stress conditions except for the fruit diameter and single fruit weight. It was observed that at 75% and 50% drought stress, its biochemical attributes, reproductive and vegetative growth reduced significantly, but proline contents in leaves were increased. Whereas, 25% drought had a non-significant effect on the growth and yield of chilli. Although none of the varieties perform up to mark under drought condition, but V_2 was better in measured parameters as compare to V_1. So V_2 may be suggested for cultivation in drought stress environments and under irrigated land of the country.

Keywords: Chilli, Drought stress, Germplasm, Screening, Tatapuri

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Introduction

Chilli ranks third position in perishable Solanaceous vegetable after tomato and potato. As a spice, chilli is utilized and sought after because of its flavor, taste, pungency and aroma. It was one of the important vegetables in diets of human in American history 7500 B.C. (Manju & Sreelathakumary, 2006). It is used as an effective drug for the treatment of joint pain and throat pain. It also diminishes heart failure risks (Bosland & Votava, 2012). It represses multiplication of various dangerous cells like bosom tumor, adeno carcinoma, respiratory malignancy (Diaz-Laviada & Rodriguez-Henche, 2014), osteosarcoma (Cho et al., 2013) hepatocellular carcinoma (Baek et al., 2008).The size of chilli ranges 4.00-7.00 mm in width, 10.00-20.00 mm in length having cone like structure. Pericarp consists of two cavities with yellowish seeds (Shao et al., 2008). Level of vitamin A is high in dried chilli. Every 100 grams of dehydrated chilli comprise 15.0 grams of fat, 10 grams of protein, 30.2 grams of sugar and 6.20 grams of fiber (Ruiz-Lau et al., 2011).

Chilli is an extremely sensitive crop to moisture stress (Gencoglan et al., 2006). Water stress conditions normally dwindling impact on composition of fruit. It also affects transportation and reception mechanisms of plants that lead to obstruction in uptake of nutrients and minerals (Garg, 2003; McWilliams, 2003).The growth of chilli is successful in areas having yearly precipitation 600.00 to 2500.00 mm (Idowu-Agida et al., 2012). Water shortage during blossoming or fruiting stage reduces aggregate fruit weight and diminishes the photosynthetic rate (Kawamitsu et al., 2000; Costa & Gianquinto, 2002). It was observed by an experiment that moisture stress has been great influenced on seedling stand (Kaya et al., 2006). Water stress halts the process of seedling development as well as seed germination in plants (Okçu et al., 2005).

Two species of chilli (*Capsicum frutescens* L. and *Capsicum annuum* L.) are under commercial production in Pakistan (Pozzobon et al., 2006). Their production is remarkably reduced because of scarcity of water. Due to unfriendly ecological conditions, for example, dry spell and salt stress, resistant mechanism must be activated for the survival rate in chilli varieties to abiotic stresses (Chartzoulakis & Klapaki, 2000). Stress applied at the stage of pre-anthesis decreases anthesis time, however at stage of post anthesis lessened seed formation in fruit (Estrada-Campuzano et al., 2008). Therefore drought resistant varieties must be identified to be portrayed to enhance the yield in result of constantly changing environment and unfriendly climatic conditions. It can contribute in poverty alleviation in water constrained areas (Zhigila et al., 2014). Keeping in view the critical effect of dry spell on chilli, this study was conducted to screen chilli germplasms to enhance yield in dry spell and to check the dry season resistance varieties of chilli.

Materials and Methods

Experimental material

The two varieties of chilli i.e. a local variety Tatapuri (V_1) and an exotic variety Bonanza (V_2) were selected. Their germplasm were obtained from NARC (National Agriculture Research Center) Islamabad, Pakistan.

Experimental plan

Seeds were sown in seedling-trays during March 2017 for development of nursery. Coco-peat was used as media. Seeds were coated with fungicide (Dithane M-45) solution (2gm/kg) before germination to avoid fungal and soil borne diseases. After 46 days, seedlings were shifted into 12-inch earthen pots with 5 kg standard potting media containing organic manure. Water stress was applied on two growth stages; vegetative stage (10 days after transplantation and reproductive stage, 1 month after transplantation with 10 days interval). Recommended dose of phosphorus, potassium and half of nitrogen were applied at the time of media preparation. Meanwhile remaining 1/2 N was applied in 2 equivalent measurements at fruiting stage.

Following four treatments with three replications were used for drought stress.

a. T_0 (controlled well-watered)
b. T_1 (75% stress)
c. T_2 (50 % stress)
d. T_3 (25 % stress)

Vegetative variables measured

Number of days from the day of transplantation to date, when half plants begin blooming were observed. The aggregate days for 50% blossoming in every replication were noted because it is an indication of earliness or late maturity of variety. Five plants were randomly selected from each entry of thirty plants to record the data regarding number of branches per plant and plant height (cm) and their height was measured when main shoot stop to grow further due to their determinate nature.

Reproductive variables measured

The number of fruits per plant picked at harvesting stage and average was calculated for each replication separately. Fruit weight was measured in grams from individual entry and then average weight of fruit was noted. Length (cm) of five fruits which was selected randomly was measured using scale/measuring tape and then average value was used for analysis. Width (fruit diameter) was measured by using vernier calipers. For this variable five fruits from every entity of each replication were chosen indiscriminately. Average value of width was used for analysis. The numbers of seeds were counted manually and five fruits from each replication were chosen randomly. The average values are recorded to be interpreted through statistical analysis. The mass of fresh fruits from randomly chosen plants was measured at picking time by using digital balance; the data from entry is summed to know the yield plant^{-1}in grams.

Biochemical parameters

Chlorophyll contents (mg g^{-1} of fresh weight)

Chlorophyll contents were measured at maturity by utilizing chlorophyll meter named spad-meter (Erwan et al., 2013). Three leaves were selected for measurement of chlorophyll contents. The values of these leaves were computed with the normal of that value.

Proline contents (µg/g)

Proline contents of sample leaves were measured using technique for content determination (Bates et al. 1973). Acid ninhydrin: solution was made by heating 1.24g ninhydrin with 30.1 ml glacial acetic acid. 19.9 ml of 6 M phosphoric acid with continuous agitation, until completely dissolved. Kept cool (refrigerated at 4°C) the reagent stays stable 24 hours. Buffer 3% Aqueous sulpho salicylic acid (Sigma CAT # 3147), Glacial acetic acid (Sigma CAT # 1005706), Toulene (Sigma CAT # 244511) and Proline (Sigma CAT # p0380) were used in this experiment. The solidified plant material was homogenized in 3.0% diluted sulpho-salicylic acid. The rest of sample isolated and then at last evacuated by centrifugation at 1.2 grams for 10 min. 1 milliliter homogenized tissue mixed with 1 milliliter of acetic acid and 1 milliliter of acid ninhydrin in a test tube at 100 °C for around 1 hour lastly following 1 hour the reaction was stopped by giving an ice shower. 2 milliliters of toluene were utilized to vacate the reaction blend, effectively blending was done and left at room temperature to set for 30 minutes till the division of two phases. Chromophore-containing toluene (1 milliliter, upper stage) at room temperature was warmed and its optical thickness was estimated at 250 nanometer utilizing toluene. D-Proline was utilized to discover the grouping of proline from a standard proline. The accompanying condition is utilized to compute the measure of proline in the concentrates.

$$Proline\ (^{\mu g}/_{g}\ tissue) = \frac{^{\mu g\ proline}/_{ml} \times ml\ toluene}{115.5\ \mu g\ /\ \mu mole} \times \frac{5}{g\ sample}$$

Where 115.5 is molecular weight of proline

Ascorbic acid contents (mg)

Ahmed et al. (2013) reported the strategy for 0.5 g from 10 fruits grinded with 10 ml of 1.0% HCL by mortar and pestle. Sample was centrifuged for 10 min at 10 thousand (rpm). Supernatant was separated and collected in cuvettes and absorbance was estimated at 243.0 nm by spectrophotometer. Vitamin C was squeezed in mg.

Statistical analysis

This research was arranged as a factorial design. The data was collected for statistical investigation by using software. The analysis of variance technique for examination of difference (ANOVA) between the applied treatments were analyzed by using least significant deviation (L.S.D) strategy to differentiate at level of 0.5% (Steel et al., 1997).

Results and Discussion

Number of days for 50% blooming

Statistical analysis demonstrated practically identical outcomes among the considered assortments of chilies in drought stress environment for number of days to 50% blooming. Maximum days to half blossoming appeared by the two assortments under control condition (Fig. 1).While, Both assortments took least days in T_1 (54.67 and 35.33 days) in contrast with T_0 (61 and 43.75 days), respectively. Chilli variety Bonanza (V_2) bloom earlier as compared to Tatapuri (V_1). There were observed 10.37 and 18.60 percent less days to 50 percent blooming in V_1 and V_2 respectively against 75 percent water stress condition. Same behaviour of early blooming of different plants was observed by the number of scientists (Bernier, 2003; Wada, et al., 2010; Li & Urban, 2016). Number of days taken to 50% flowering by the plant is a critical aspect as it portrays the status of early maturing and late development of characteristic of any variety. Because of natural conditions plants adjust developmental and growth processes (Hopkinson, 1977). But in stress condition plant bloom earlier (King et al., 2008). Plant produce viable seed in response of stress condition and these seeds produce normal and healthy progeny (Wada, et al., 2010).

Stress-activated transition to flowering improves the probability of surviving of a plant population in the harsh-ecological conditions (Li & Urban, 2016). This phenomenon is an emergency response when plant is in stress; ensure production of the next generation (Shimakawa et al., 2012). Even though the flowering process is not actually promoted but flowering is accelerated to complete the life cycle by generating new generation in the form of seeds (Bernier, 2003). Different hereditarily controlled ways are being utilized for the progress to a reproductive stage from a vegetative stage (Fornara et al., 2010). Higher concentrations of salicylic acid (SA) assimilation are responsible for early blooming in plants under stress (Shimakawa et al., 2012). SA accumulation triggers miR169 impacts in numerous plant species (Yin et al., 2012). Such as in Arabidopsis, miR169d-mediated regulation of AtNF-YA genes has crucial impact in flowering time control. Early blooming may come about due to over expression of miR169d, and late flowering because of AtNF-YA2 would bring about late flowering (Xu et al., 2009). Endogenous GAs participates in controlling blossom time through the up-regulation of genes, for example, LFY and SOC1 (Moon et al., 2003). Early blossoming might be because of photosynthetic deficiency because it is a bloom initiating factor (Bernier & Perilleux, 2005). Reduction in the quantity of blossoms is related to drought at pre-anthesis decrease the time for anthesis (Estrada-Campuzano et al., 2008). Therefore, many biological advantages be accomplished by the stress induced blooming, and this is as important like vernalization and photoperiodic flowering (Wada et al., 2010).

Number of branches plant^{-1}

Statistical analysis demonstrated variation in outcomes among the considered assortments of chilies under drought stress conditions for number of branches plant^{-1}. The results indicated that there were more number of branches plant^{-1} produced by V_1 (48.00) and V_2 (44.83) respectively in sufficient water condition T_0 (Fig. 2). While in drought conditions (T_1) 44% reduction in V_1 along with 26 branches per plant and somewhat less reduction 33.2 % in V_2 i.e. 30 branches per plant was observed. Current research outcomes revealed that a remarkable difference was found between the varieties and extremely important alterations were detected between the analyses for number of branches^{-1} plant with different levels of stress. Similar result came about the lack of water system, noteworthy consequences on developmental growth of plant parameters of pepper in case of deficit water supply number of branches were decreased (Tadesse, 1997).

Number of branches directly influences the quantity of fruits per plant. Chilli plant begins flowering at the first axial node with subsequent flowers forming at each additional node which means that the availability of fruiting sites is directly proportional to number of branches (Bosland & Votava, 2012). Adequate moisture content is basic need of plant development, growth and quality (Manivannan et al., 2008). Ecological stress conditions give raise the pH level of leaf sap along with expanding the transpiration rate, this causes reduce stomata conductance along with abscisic acid accumulation (Wilkinson

& Davies, 2002). Water deficit is responded by plants utilizing avoidance mechanism by enhanced root length (Price et al., 2002). ABA provokes root development. At high ABA levels, endogenous hormone causes a significant result on root development by influencing ethylene production to lower and shows a minor negative impact on shoots development (Taiz & Zeiger, 2010). Decrease in cell division and elongation results a diminished yield development, leaf area and, plant height under dry season (Kaya et al., 2006). Phenotypic dwarfism is aggregate impact stress conditions which eventually diminish number of branches (Hussain et al., 2008).

Plant height (cm)

Noteworthy impacts of drought on height of plant are found among the applied treatments and varieties. Maximum plant height was recorded in T_0 (71.50 cm) followed by T_3 (67.167 cm) and the other treatments in V_1 (Fig. 3). A similar set of results was recorded in V_2 as T_0 showed most astounding plant height (88.33 cm) and least was seen in T_1 (76 cm). Plant height was altogether diminished in treated plants. T_1 displayed greatest stunted development (56.5 and 76 cm) for V_1 and V_2, respectively. In V_1 reduction was 17.24% and in V_2 reduction recorded as 13.95% in severe water stress condition. The same plant behavior was quoted by the following researchers. Reduction in cell elongation and decreased photosynthetic activity causes phenotypic dwarfism in growth of plant in dry spell (Kaya et al., 2006; Hussain et al., 2008).

Lowering cell volume and cell shrinkage occurs because of desiccation (Hoekstra et al., 2001). Under extreme water deficiency, cell elongation becomes compelling variable in higher plants because of interruption of water flow (Nonami, 1998). Accumulation of ABA can also be cause of induction of resistance in extreme ecological conditions (Thompson et al., 2007). Rise in calcium ions in plant leaf cells cytoplasm due to accumulation of ABA which brings about the reactive oxygen species (ROS) generation, depolarization of the plasma layer occurs because of the anion efflux. The turgor pressure in guard cell decreases due to efflux of potassium and anion efflux that leads to stomatal closure (Vahisalu et al., 2008). Reduction in leaf area is responsible for untimely leaf senescence at premature stage and impairs the photosynthetic apparatus (Ahmad et al., 2005). It has also been reported about the Stunted plant height is because of the reduction in turgor pressu
re (Taiz & Zeiger, 2010). Maximum plant height in T_0 is because of Stomatal responses to drought, which must be balance between keeping water loss and preventing from over-warming. Reduction in stomatal conductance is seen to limit transpiration rate for keeping up ideal turgor weight in plant cell (Mittler & Blumwald, 2010).

Number of fruits per plant

Two varieties differ potentially in numbers of fruits per plant at various drought treatments investigated by analysis of variance. The highest no of fruits plant^{-1} i.e. 96 and 123 was estimated for (V_1) and (V_2), respectively in control condition (T_0) but minimum number of fruits per plant i.e. 57 and 82.33 were calculated for V_1 and V_2, respectively under extreme stress condition T_1 (Fig. 4). Statistically, the comparison between the number of fruits plant^{-1} and the treatments was remarkable. No of fruits plant^{-1} were configured for V_1 i.e. T_0: 96, T_1: 57, T_2: 70 and T_3: 88 fruits per plant, whereas in V_2 i.e. T_0: 123, T_1: 82.33, T_2: 92.33 and T_3: 113.0 fruits plant^{-1}, under different conditions. It was around 52% reduction for number of fruits plant^{-1} between the control and at 75% stress. The total number of fruits per plant is influenced by ecological factors and it is polygenic characteristic. The same results were obtained for *C. annuum* by Bakker (1989); Marcelis et al. (2004). Chilli bears the fruit at axial nodes of plant that is one of the main reasons of reduction of fruit production. Under stress conditions, number of branches plummet is observed which ultimately declining the fruit sites availability of the plants (Bosland & Votava, 2012). For healthy growth and development tolerable soil moisture is very important (Manivannan et al., 2008).

Single fruit weight (g)

The overall variation among drought stress treatments applied for single fruit weight was significantly high. The V_1 and V_2 gained highest per fruit weight i.e. 9.75 and 9.17 g, respectively at controlled condition (T_0) whereas least weight of a single fruit (4.67 and 4.58 g, respectively) was recorded at 75% moisture deficit in T_1 (Fig. 5). The observations were accordance with the past finding of Ruiz-Lau et al. (2011), who observed a decline in this attribute in the water stressed plants fruit compared to the controlled condition plants. The physiological mechanism rotates around the stomatal regulator of transpiration originated biochemical responses through the root (e.g. abscisic acid) fleeting to leaves from drying roots (Stoll et al., 2000). Crop growth, leaf area and plant height, is decreased under moisture stress (Hussain et al., 2008). Stress-induced changes in cytokinin and ABA provokes early leaf senescence causing to leaf abscission, hormonal variations and results in reduced water loss, and smaller canopy (Pospisilova et al., 2000). Root and shoot biomass lessens by drought, due to restricted photosynthetic activity and root respiration (Li et al., 2008). This reduces the division in cell at the developmental stage of embryo/endosperm, causing in weak sink intensity, and probably results in fruit abortion and less fruit weight (Andersen et al., 2002).

Fruit length (cm)

Chilli fruit length was also affected significantly due to drought stress. The two types of chilies i.e. V_1 and V_2 are found to have maximum length of 7.27 and 8.93 cm, respectively under control condition T_0 (Fig. 6). However, in

T_1 treatment fruit length 5.57 and 7.67 cm were recorded for V_1 and V_2, respectively. Due to amplified drought stress a noteworthy length reduction of 23.39% in V_1 and 14.17% in V_2 was observed. While in mild stress condition no significant results observed in both varieties. The outcomes were found in accordance of Ruiz-Lau et al. (2011), who came up with the claim that the fruits length is highly dependent on the availability of irrigation. For normal healthy growth and crop developmental progress the tolerable soil moisture is essential (Manivannan et al., 2008). The reduced chlorophyll concentration and chlorophyll fluorescence can be counterbalance in the stress tissues by the improved biochemical activity under water stress and reduce enzymatic activities in leaves and roots (Sofo et al., 2004). Reduction of photosynthesis and reduction in cell growth i.e. cell elongation is an outcome of phenotypic dwarfism in development of crop under drought (Kaya et al., 2006; Hussain et al., 2008). The decrease in fruit size was observed due to the severe water stress (Khan et al., 2008).

Fruit diameter (cm)

Variance analysis showed a high difference in fruit diameter among all treatments that were done at various level of drought on two different chilli varieties. Under controlled condition (T_0) the both chilli varieties showed the fruits' diameter at maximum level (Fig. 7).While these varieties V_1 and V_2 showed minimum fruit diameter at 75% drought stress conditions (T_1). However, fruit diameter was significantly reduced when drought stress was increased. Both (V_1) and (V_2) varieties got fruit diameter against the treatments as follow; (T_0) 1.92 cm and 1.67 cm followed by (T_3), 1.205 cm and 1.522 cm and (T_1) 0.88 cm, 0.96 cm, respectively. Almost the same result was reported by Zhigila et al., (2014). The plant enlargement, cell division, and overall growth can be seen as qualitative and quantitative parameters that are being affected by water stress (Cabuslay et al., 2002). Reduced photosynthesis may cause less fruit diameter due to under development of fruit. Similar findings were also recorded by (Sayyari & Ghanbari, 2012). Fruit diameter and its length were decreased due to shrinkage of the cell and due to lack of photosynthesis process. Reduction of photosynthesis and reduction in cell growth i.e. cell elongation is an outcome of phenotypic dwarfism in development of crop under drought (Kaya et al., 2006; Hussain et al., 2008). The decrease in fruit size was observed due to the severe water stress (Khan et al., 2008).

Number of seeds per fruit

Analysis of variance (ANOVA) showed that different treatments results in a highly significant outcome at various levels of drought stress. Highest number of seeds fruit^{-1} for V_1 and V_2 (49.67 and 52.33 respectively) (Fig. 8) were found in controlled condition (T_0). These numbers of seeds per fruit are highly varied from drought prevailing environment. Minimum no of seeds fruit^{-1}were found 39 and 43 in V_1 and V_2, respectively on 75% moisture stressed treated plants in T_1. Alike observations were also provided by Zhigila et al., (2014). Research results was in accordance with Abayomi et al. (2012), who explained that plant development attributes including per plant area of leaves and their numbers, plant height and seeds per plant were reduced because of less moisture in the planted soil. Polygenic characteristics includes, no of seeds fruit^{-1}affected by a lot of environmental factors which imparts a vital role in growth of plant and production of final stage. More number of seeds fruit^{-1} guarantee higher yield of the crop. Excessive loss of water and imbalance photosynthesis causes the shrinkage of cell and this means the declination of the cell volume (Hoekstra et al., 2001). Less seeds per plant are a factor that arises due to reduce fruit length. When there is deficit of irrigation (drought stress) is found while harvesting the pepper plant the final yield showed a very prominent decrease in the diameter of the fruit and its weight for which the pepper plant is the most sensitive to drought (Zhigila et al., 2014).

Yield per plant (g)

The yield outcome was monitored under both environmental conditions like drought stress and controlled conditions and the data was recorded and analyzed for both of the chilli varieties. The LSD values indicated chilli varieties show a different trend in yield outcome grown in drought stress condition as equated to controlled condition. Least value of yield was recorded in (T_1) 260.87 g plant^{-1} for V_1 (Fig. 9). Maximum crop yield was exhibited by V_2 with 1199.5gm plant^{-1} in T_0, while in T_3, T_2 and T_1 yield was 857, 562.08 and 389.33 g plant^{-1}, respectively. Yield for V_1 in T_0 was 879.5 g plant^{-1} but in T_3, T_2 and T_1 689.5, 460.5 and 260.89 g plant^{-1}, respectively were recorded. Chilli yield showed an inverse correlation with the drought condition, the results are in accordance with Iwo et al. (2016) and mentioned significant alterations under drought stressed conditions in chilli crop production. The water stress cause a reduction of photosynthesis process in plant development process (Romero et al., 2013). Some of the slower enzymatic activities like reduce chlorophyll concentration and decrease chlorophyll fluorescence in plant leaves and plant roots due to water stress as an outcome of increased biochemical activities in stressed tissues (Sofo et al., 2004). Less number of branches and phenotypic dwarfism cause the less availability of the fruit sites (Bosland & Votava, 2012). Chilli crop yield can loss up to 50-60% due to drought stress (Malhotra, 2017).

Chlorophyll contents

Statistically analyzed data depicted that deficiency of water caused remarkable reduction of chlorophyll substance in hot pepper. Highest concentration of chlorophyll content was observed in treatment T_0 (54.93 and 57.14 by V_1 and V_2, respectively) in correlation with T_1 (33.73 and 38.42 by V_1 and V_2, respectively) (Fig. 10). Chlorophyll content was essentially diminished by limited water supply. Under moisture deficit, chlorophyll content level reduction has been estimated as a main indication of oxidative stress and degradation of chlorophyll.

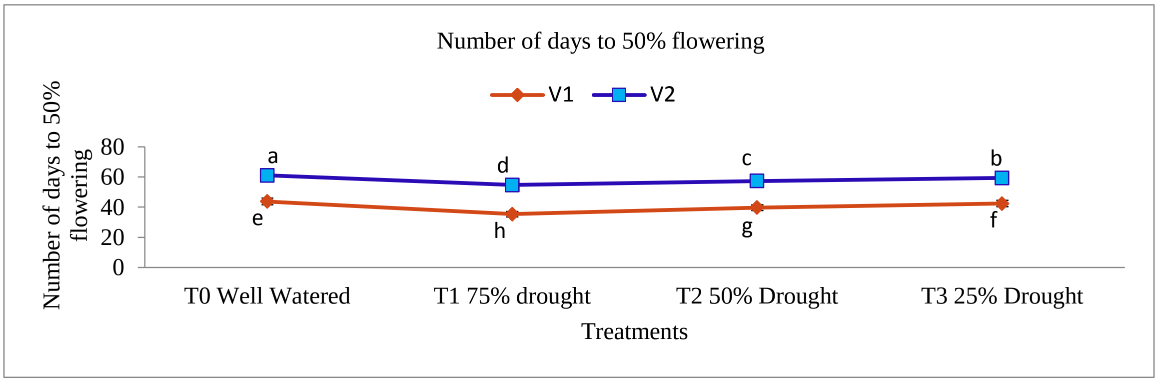

Fig. 1 Effect of different water stress treatments on days to 50% flowering of chilli varieties

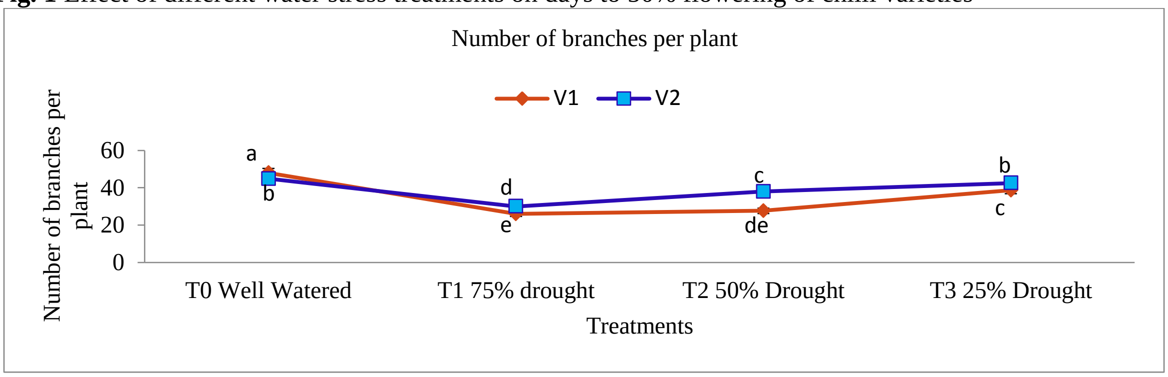

Fig. 2 Effect of different water stress treatments on number of branches per plant of chilli varieties

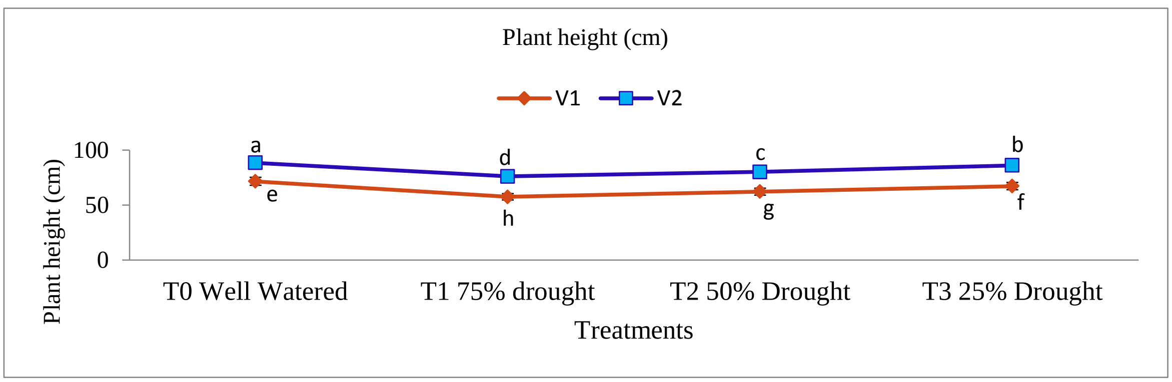

Fig. 3 Effect of different water stress treatments on plant height (cm) of chilli varieties

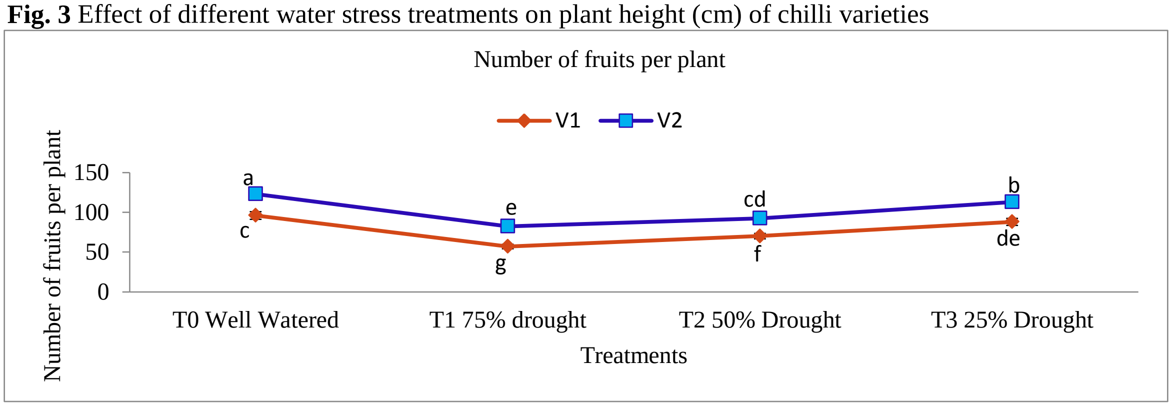

Fig. 4 Effect of different water stress treatments on number of fruits per plant of chilli varieties

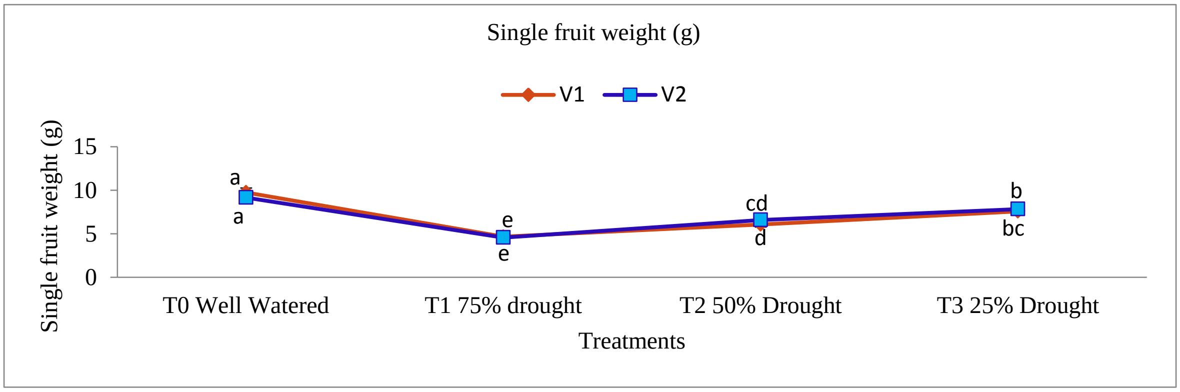

Fig. 5 Effect of different water stress treatments on single fruit weight (g) of chilli varieties

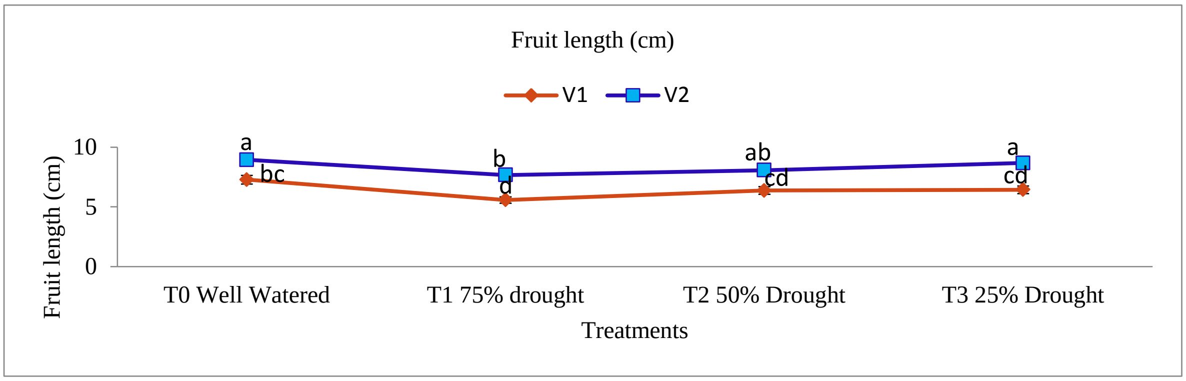

Fig. 6 Effect of different water stress treatments on fruit length (cm) of chilli varieties

Awasthi et al. (2014) reported that abiotic stress condition including salt, cold, warm, oxidative stress, nutrient insufficiency and dry spell is the fundamental reason of crop damage globally, decreasing both the quality and the average yield. Moisture stress diminished growth, chlorophyll content, photosynthetic rate and osmotic potential. However, the collective stress had a higher negative impact than each of the individual conditions separately (Ahmed et al., 2013). Photosynthetic colors are significantly important to plant for the most part to collect light which help in manufacturing of reducing powers. Reduced chlorophyll level in moisture deficit abiotic stress has been stated for in numerous varieties, which depend upon the period and sensitivity to dry spell (Kyparissis et al., 1995; Zhang & Kirkham, 1996).At the point when plants are subjected to abiotic stresses by means of destabilization of Rubisco and damage to Photosystem II (Nishiyama & Murata, 2014). As osmotic pressure causes a series of biochemical, physiological, morphological, and molecular changes that alter plant efficiency, productivity and development around the world.

Proline contents

Inspection of proline level demonstrated that the range of proline content was (4.41-10.09 µg g^{-1}) in V_1 and (5.04-12.27 µg g^{-1}) was recorded in variety V_2 (Fig. 11). The maximum level was observed in treatment T_1 at 75% moisture stress condition while the most minimal measure of the proline was noticed (4.41 µg g^{-1}) and (5.04 µg g^{-1}) in V_1 and V_2 at control condition T_0 respectively. These results depicted that water scarcity promotes the proline content in leaf. However; the 75% moisture stress had most prominent impact in enhancing production of proline in leaf. Current discoveries are also in accordance with the past consequences of drought altered the concentration of mineral, proline and phenol in pepper significantly (Fiasconaroa et al., 2019). As in experiment by Ichwan et al. (2017) who portrayed that dry spell resistance chilli will improve proline content that retain the sugar and total chlorophyll content.

In scarcity of water physiological variations happen which also include declining in photosynthetic activity, reduced stomatal conductance, decreased chlorophyll fluorescence, loss of membrane stability, pigment degradation, growth and development inhibition before to plant expiry, reduced internal CO_2 concentration, and reduced leaf water potential (Shao et al., 2008). Under stress conditions, inhibition of Rubisco and average osmolytes (polyamines, polyamine, glycinebetaine, α-tocolpherol, sugar alcohols, proline, sugars and glutathione) movement observed. Stress conditions also improved levels of antioxidants (glutathione reductase catalase, ascorbate peroxidase and superoxide dismutase) to reduce damage to the plants (Cha-Um et al., 2009). Proline and its metabolite are discriminatory amino acids both biochemically and chemically (Hu et al., 2008). Proline production is the primary reaction of plants exposed to water-deficiency, stress to reduce cell injuries by utilizing osmotic adjustment, salt stress, anti-oxidative activity and organelle stabilization (Ashraf and Foolad, 2007). Proline production is higher in plants subjected to stress ecological conditions (Molinaria et al., 2007). Proline has a substantial impact in imparting plants resistance to stress that lower the water capability of ambient environment believed by many researchers (Schat et al., 1997). Proline accumulation protects cells from water stress by expanding the antioxidant activity (Mohanty & Matysik, 2001). Thus, when stress applied to the plant; proline appears to play a role to balance out DNA, proteins and membranes (Matysik et al., 2002).

Ascorbic acid contents

The statistical analysis showed remarkable contrast for vitamin C level in both varieties. Higher contents of ascorbic acid in both varieties was seen in (T_0) the estimations of 1.830 mg, 1.970 mg which was lagged behind by T_3 with 1.53 mg, 1.80 mg, T_2 with 1.33 mg and 1.60 mg (V_1 and V_2, respectively) (Fig. 12). Whereas minimum value was observed in $T_1$where the estimations were recorded 1.17 mg for V1 and 1.47 mg for the V_2. Results for vitamin C in the two assortments (V_1 & V_2) demonstrated after drought expanded, the amount of ascorbic acid diminished and the likewise for inverse relation. Level of vitamin C in chilli relies upon a few factors, for example, cultivar, ecological conditions and cultural practices (Kumar et al., 2001). Negligible correlation was observed in between vitamin level and capsaicin level provides a source to improve cultivars with more nutritive substance for sense of taste of consumer with the high content of ascorbic acid level (Geleta & Labuschagne, 2006). Chilli is a rich source of phytochemicals, for example, vitamins (Zhuang et al., 2012). Ascorbic acid is the fundamental compound and is another practical and dietary constituent of pepper natural product (Teodoro et al., 2013). It is outstanding as antioxidant agent and bioactive compound, especially in ripe peppers (Kim et al., 2011). Ascorbic acid is cancer prevention agent and has notional value, is available in chilli assortments at two-fold in level as in apples, tomatoes or oranges gram^{-1} to the weight of fruit (Wahyuni et al., 2013).

Conclusion

Keeping in sight of above debate it was concluded that, the significant variability was found among the experimented chilli varieties for characters examined. The chilli assortment V_2 (Bonanza) demonstrated more resistance drought stress season as compared to the local variety (Tatapuri) V_1. The variety (V_2) also showed superior performance in control conditions. A negative relationship was found between drought stress and all other characters which were studied except proline contents for both V1 and V2 varieties. Due to stress resistance character exotic hybrid variety Bonanza is commercially recommended in arid region to save water in stress condition with minimum loss in production and nutritional attributes.

Author Contribution Statement: Kinza Khan conducted the experiments and collected the data. Najma Yousaf Zahid supervised the research study. Abdul Ahad Qureshi wrote the manuscript. Khalid Mehmood analyzed the data.

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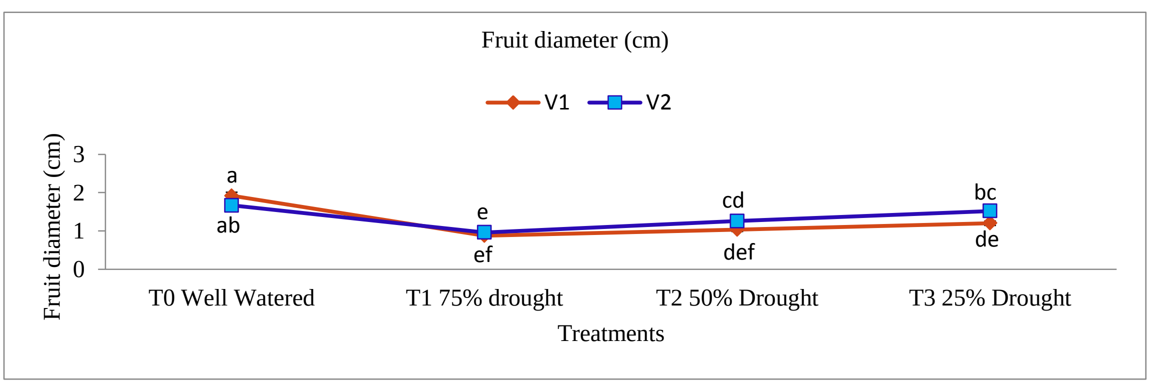

Fig. 7 Effect of different water stress treatments on fruit diameter (cm) of chilli varieties

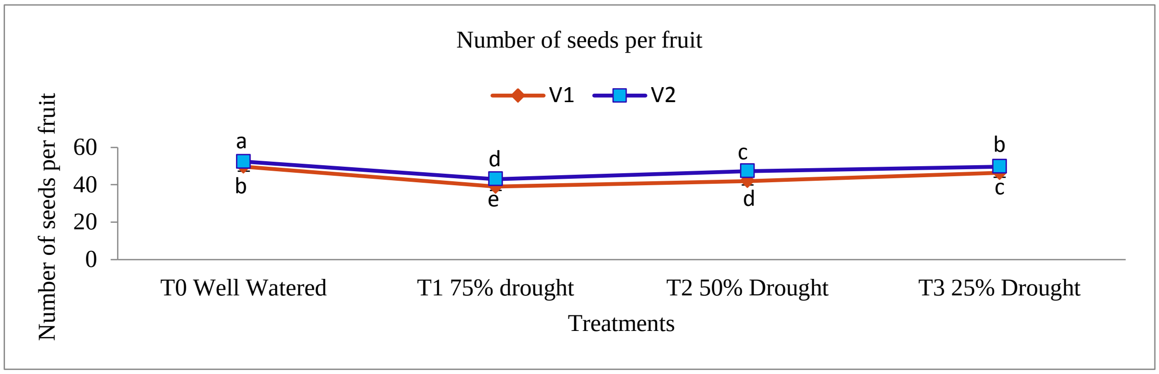

Fig. 8 Effect of different water stress treatments on number of seeds per fruit of chilli varieties

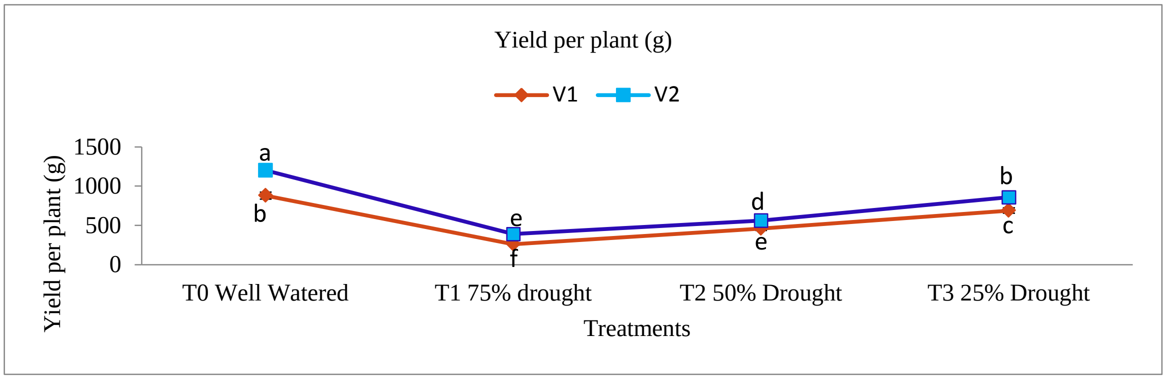

Fig. 9 Effect of different water stress treatments on yield per plant of chilli varieties

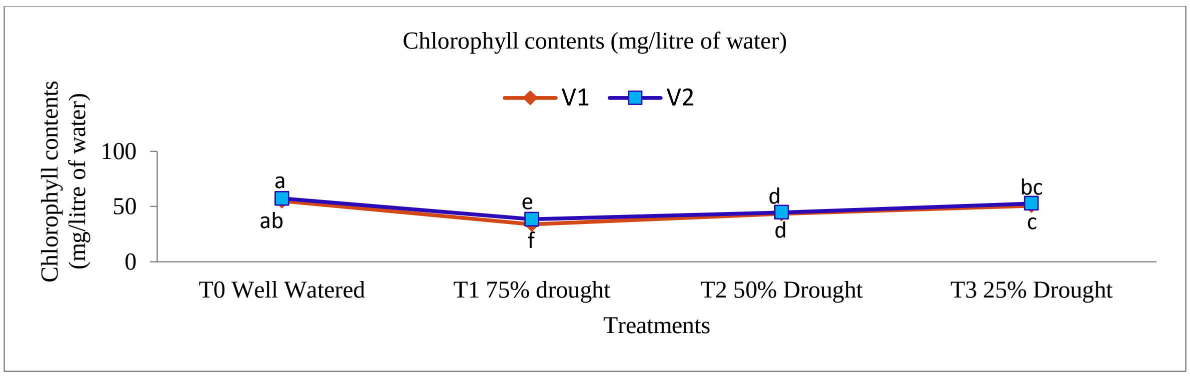

Fig. 10 Effect of different water stress treatments on chlorophyll contents in the leaves of chilli

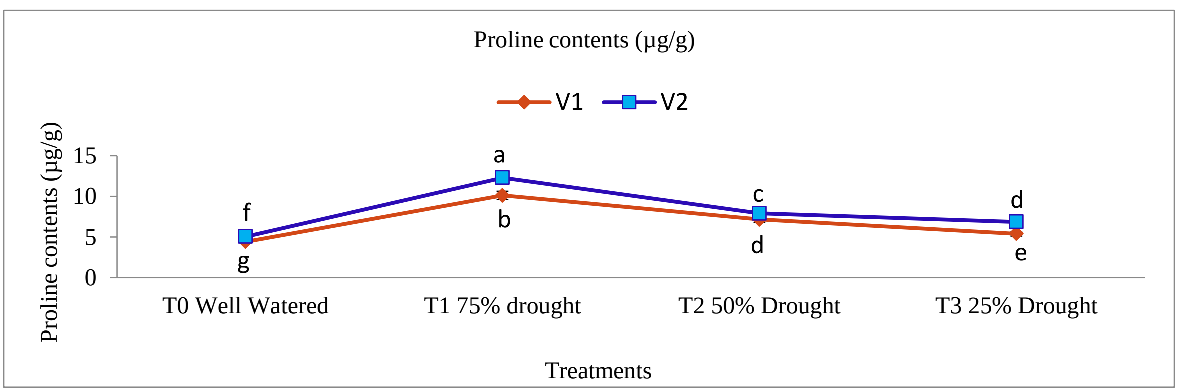

Fig. 11 Effect of different water stress treatments on proline contents of chilli varieties

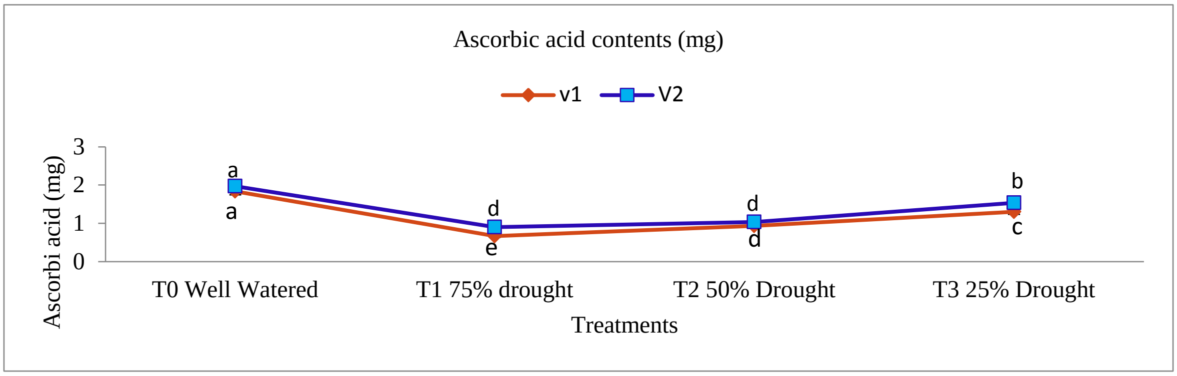

Fig. 12 Effect of different water stress treatments on ascorbic acid contents in fruits of chilli

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