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Expediency of water and soil nutrients in irrigated and extreme drought conditions

Muhammad Zubair[1*], Lal Hussain Akhtar[1], Rashid Minhas[1], Muhammad Javed Qamar[2], Shah Jahan Bukhari[1], Attiq Sadiq[3], Sabir Hussain[3], Ali Ammar[4] and Muhammad Kashif Aziz[4]

[1]Agricultural Research Station, Bahawalpur, Pakistan.
[2]Soil and Water Testing Lab for Research, Bahawalpur, Pakistan.
[3]Cotton Research Station, Bahawalpur, Pakistan.
[4]Regional Agricultural Research Institute, Bahawalpur, Pakistan.

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Climate change has become global issue for crops due to increase in temperature and less rainfall resulting in shortage of water and decrease in yield. The experiment consisted of five guar (*Cyamopsis tetragonoloba* L.) genotypes viz. S-5744, S-5824, S-5785, BR-90, BR-99 were cultivated under irrigated and drought stress (only soaking dose) conditions using Randomized Complete Block Design (RCBD) with 3 replications. The data for yield and its components were recorded at the time of maturity of guar genotypes. The two genotypes S-5744 and S-5824 showed better performance under both drought and irrigated conditions and gave maximum yield 900 and 1133.33 grams in drought and irrigated, respectively. All characters showed positive correlation with each other except number of cluster plant^{-1}. The soil analysis was done in order to check availability and utilization of nutrients in the presence of water (irrigated conditions) and water deficit conditions (drought). The above mentioned two genotypes were less affected by the water shortage compared to others and were comeback after rainfall in the months of July and August and have ability of better uptake of nutrients from the soil in drought and irrigated conditions. However, nutrient use was higher under irrigated conditions.

Key words: Utilization, nutrient uptake, soil and temperature, drought.

INTRODUCTION

On the global level, climate change has become an issue of severe and immediate concern having far-reaching effects not only on agricultural productivity but also on the demand for water and energy. During the past century, global temperatures have risen by nearly 1°C (due to burning of hydrocarbons and deforestation) and are expected to increase further by 1.4 to 5.8°C by the year 2100 (Naseer, 2013) .

In the past few years, the situation has worsened and signs of global warming are becoming evident. With

*Corresponding author. E-mail: muhammadzubair1483@gmail.com. Tel: 092 333 6201183.

climate change, in addition to higher average temperatures, there is an increased risk of rising sea levels, melting of glaciers, flooding and higher frequency of droughts. Consequently, crop yields are expected to decrease, affecting livelihoods and food production (Naseer, 2013). According to Jamshed Iqbal Cheema (Chairman: Pakistan Agricultural Scientists Association), per capita water availability at the time of independence was 5,600 m^3 against the current measure of 1,000 m^3 and the shortage is expected to rise to 31% of people's needs by 2025 (Naseer, 2013).

In this current situation of climate change and water shortage, guar crop plays an important role being highly drought resistant legume crop. Guar (*Cyamopsis tetragonoloba* L.) is a summer annual legume crop and commercially known as cluster bean (Kobeasy et al., 2011; Rao and Shahid, 2011). It is a highly drought tolerant and multi-used crop because it is used in gum industries, green manure, animal feed and fodder (Sharma and Gummagolmath, 2012). It is mainly cultivated in Pakistan and India as forage for cattle and vegetable for humans (Rao and Shahid, 2011) under arid/semiarid areas of the world preferring hot dry environment (Sharma and Gummagolmath, 2012; Sultan et al., 2012). Like other legume crops, guar is also an exceptional crop to enhance soil fertility as it can fix atmospheric nitrogen (Bewal et al., 2009; Sultan et al., 2012).

It has been observed that nitrogen fixation and nodulation are more sensitive to environmental stresses including water stress. Water stress has been reported to suppress O_2 flux in nodules or supply of photosynthates, consequently causing a decrease in nitrogen fixation (Silvente et al., 2012). Lotter et al. (2014) observed that net photosynthetic rate decreases under water limited conditions that can affect nutrient allocation and biomass in a legume *Aspalathus linearis*. Legume crops play an important role in the economy of arid and semiarid areas of the world as they are the major source of protein (Sohrawardy and Hossain, 2014). Legumes help in improving soil fertility because of their inherent capability to fix atmospheric nitrogen (Sohrawardy and Hossain, 2014).

Genetic diversity is one of the important factors to improve many crops including guar (Sultan et al., 2012). It was observed that little water requirements of guar help in showing more potential to salinity, consequently to obtained fast-growing high quality forage (Rao and Shahid, 2011). Stafford and McMichael (1991) reported that yield of guar plants was more affected than seeds/pod, seed weight and racemes/plant under water limited conditions.

Comeback of plants against stress depend upon the genetic makeup of cultivar, severity and period of the stress and vegetative and reproductive stage of plant (Khan et al., 2011; Razzaq et al., 2013). Due to stomatal closure, photosynthetic effectiveness of the majority of plants undergoes suppression under drought stress, which limits diffusion of CO_2 in leaf (Ali and Ashraf, 2011).

The objective of this study was to identify impact of extreme drought conditions and availability and utilization of nutrients by plants from drought soil, including its effects on yield and other characters such as Number of Cluster plant^{-1}, Number of Seeds pod^{-1} and Number of pods plant^{-1}. Soil and crop management practices to alleviate negative effects of drought and heat stresses are also discussed. Investigations involving determination and identification of most stress-tolerant plant genotypes are essential for understanding the complexity of the responses and for future plant breeding.

MATERIALS AND METHODS

The experiment was conducted at experimental field of Agricultural Research Station, Bahawalpur at latitude and longitude of 29.3957°N, 71.6833°E and altitude 461 m, respectively. The experiment consisted of two sets (drought and irrigated) with five genotypes including two check varieties for comparison. The experiment was sown in Randomized Complete Block Design (RCBD) with three replications keeping plot size of 2.7 x 7.2 m. In Drought set, only soaking dose was applied for proper germination followed by no irrigation during whole growing season while in irrigated set, 4 irrigations were applied at different stages of plant growth.

Eight soil samples were collected from experimented field i.e 4 samples before sowing and 4 samples after harvesting at 6 and 12 inches depth in order to check the utilization of nutrients by plants in irrigated and extreme drought soil conditions. The S1B3 and S2B3 are soil sample taken from drought field set before sowing and after harvesting of guar crop at 0 to 6 inches and 6 to 12 inches depth, respectively while S1B4 and S2B4 were soil sample taken from irrigated set at depth of 0 to 6 and 6 to 12 inches, respectively. The nutrients utilized by plants were calculated by subtracting the nutrients value obtain from soil analysis after harvesting to the nutrients value of soil analysis, before sowing of crop. Soil samples were got analyzed from Soil and Water Testing Laboratory, Bahawalpur in order to check the available utilized nutrients in soil before and after sowing of guar.

Procedure for soil nutrients analysis

Extraction of nitrogen (Nitrate NO_3^-) and organic matter

Turn on the balance, set a weigh boat on top, and zero the balance. Use a spatula to weigh out 10 g of soil (dried and sieved) and transfer to a labeled 100-mL beaker. Weigh out 0.1 g of calcium sulfate and transfer it to the beaker. Using a 25-mL graduated cylinder measure 20 mL of deionized water and transfer to the beaker. Repeat steps for each nitrogen soil sample. Thoroughly mix the contents of each beaker with a stir rod. Secure samples on a table-top shaker and shake for 1 min.

Extraction of phosphorus and potassium

Turn on the balance, set a weigh boat on the top, and zero the balance. Use a spatula to weigh out 2 g of soil (dried and sieved) and transfer into a labeled 100-mL beaker. Use a 25-mL graduated cylinder to measure 20 mL of Mehlich 2 soil extractant into the cylinder. Transfer to beaker. Repeat steps for each phosphorus and

Table 1. Soil analysis before sowing and after harvesting of guar crop.

S/No	Detail		Organic matter (%)			Nitrogen (%)			Available Phosphorus (ppm)			Available Potassium (ppm)		
	Acre No.	Depth (inches)	BS	AH	UB P	BS	AH	UB P	BS	AH	UB P	BS	AH	UB P
1	S1B3	0-6	0.98	0.31	0.67	0.51	0.16	0.34	7.1	7	0.1	169	125	44
2	S2B3	06-12	1.24	0.26	0.98	0.64	0.13	0.50	8.2	7.5	0.7	213	121	92
3	S3B4	0-6	1.29	0.46	0.83	0.67	0.23	0.43	7.3	6.3	1	249	80	169
4	S4B4	06-12	1.03	0.31	0.72	0.53	0.16	0.37	6.9	4.7	2.2	253	75	178

Note: BS (soil analysis before sowing of guar crop), AH (soil analysis after harvesting), UBP: [BS-AH](Nutrients utilized by plants).

potassium sample. Thoroughly mix the contents of each beaker with a stir rod. Secure samples on a table-top shaker table and shake for 5 min.

Nutrient extraction filtration - This step will be performed for all three analyses (nitrate, phosphate, and potassium)

Secure one end of the funnel hose onto a vacuum jet and the other to the side arm of the flask. Assemble the funnel by snapping together the cylinder and perforated top disk. Place the assembled funnel on the side-arm flask by inserting the rubber stopper on top of the flask, to secure the funnel and place 1 clean filter paper on top of the funnel. Turn on the vacuum jet.

Slowly pour soil extract solution into the funnel, allowing the extract to drain away from the soil into the bottom of the funnel flask. Pour filtered extract into a new, labeled 50-mL beaker. This filtrate will be analyzed as is. Remove funnel, discard filter paper, and rinse funnel and flask with deionized water. Use air jet to dry funnel and flask. Repeat steps for each soil sample.

The climatic data was also recorded from internet weather website of Bahawalpur location regarding maximum, minimum and average temperature, dew point, humidity and rainfall. One bag of DAP fertilizer was added to field before sowing of drought and irrigated sets. The data were recorded from five randomly selected plants of each genotype of the following traits i.e. Plant height (cm), number of clusters plant^{-1}, pod length (cm), number of seeds pod^{-1} and number of pods plant^{-1} from both irrigated and drought fields. Then, total and average five randomly selected plants from three replications were calculated. The average data of three replications was subjected to analysis of variance (ANOVA) and correlation among characters by statistical tool for agricultural research (STAR) version: 2.0.1 software.

RESULTS AND DISCUSSION

Nutrient uptake

The soil analysis was completed for drought and irrigated set before sowing and after harvesting of guar crop, which revealed that plants utilized available nutrients (Organic Matter, Nitrogen, Phosphorous and Potassium) present in the soil.

The organic matter utilized by plants was 0.67 and 0.98% in S1B3 and S2B3 while 0.83 and 0.72% in S1B4 and S2B4, respectively. The available soil Nitrogen, Phosphorous and Potassium were utilized by plants in drought set (0.34, 0.50%), (0.1 and 0.7 ppm) and (44, 92 ppm), at depths of 6 and 12 inches, respectively. S1B4 and S2B4 revealed that plants utilized maximum available of soil organic matter (0.83, 0.72%), Nitrogen (0.43, 0.37%), Phosphorous (1, 2.2 ppm), and potassium (169, 178 ppm) (Table.1). From these values it is clear that genotypes in irrigated conditions used more soil nutrients as compared to genotypes in drought conditions.

The maximum uptake of nutrients to plants is only possible with availability of water in soil and genotypes in drought set remained in stress during the May and June due to high temperature (41.52°C) and (41.83°C) and low precipitation (0.51 mm). Guar is known for its drought tolerance and grows without irrigation even in areas with as little as 250 mm of annual rainfall (Undersander et al., 1991). The plants in drought set were recovered in the months of July and August because of low temperature and rainfall (11.93 and 69.85 mm) as compared to May and June and uptake of the available nutrients in soil (Table 2). Two genotypes i.e. S-5744 and S-5824 performed well in both drought and irrigated conditions which gave maximum yield (1133.3 and 1300 g) as compared to other genotypes with yield 900 and 666.67 g.

Plant height (cm)

Genotypic Mean Square (GMS) for plant height (284.5507) and Genotypic F value showed significant results at 5% level of significance (24.50) in drought set while irrigated set also showed significant results for plant height with highest GMS (1930.6293) which showed significant results (1.74) in irrigated conditions, indicating the existence of variations among the

Table 2. Weather data of 7 months during guar crop season 2016.

Month	Temperature (°C)			Dew point (°C)			Humidity (%)			Precipitation (mm)
2016	High	Avg.	Low	High	Avg.	Low	High	Avg.	Low	Total
May	41.52	34.71	28.03	21	17.58	14.097	53.87	35.19	15.94	0.51
June	41.83	36.3	30.4	24.1	21.37	18.433	58.23	41.33	22.87	0.51
July	38.77	33.97	29.23	26.5	25.1	23.355	74.48	57.39	37.55	11.93
August	36.81	32.06	27.74	26.7	25	23.226	79.45	63.84	43.35	69.85
September	36.93	31.97	26.93	24.6	22.9	21.3	75.53	57.93	35.47	3.05
October	35.68	28	20.52	19.6	17.87	15.452	72.65	51.1	24.77	0

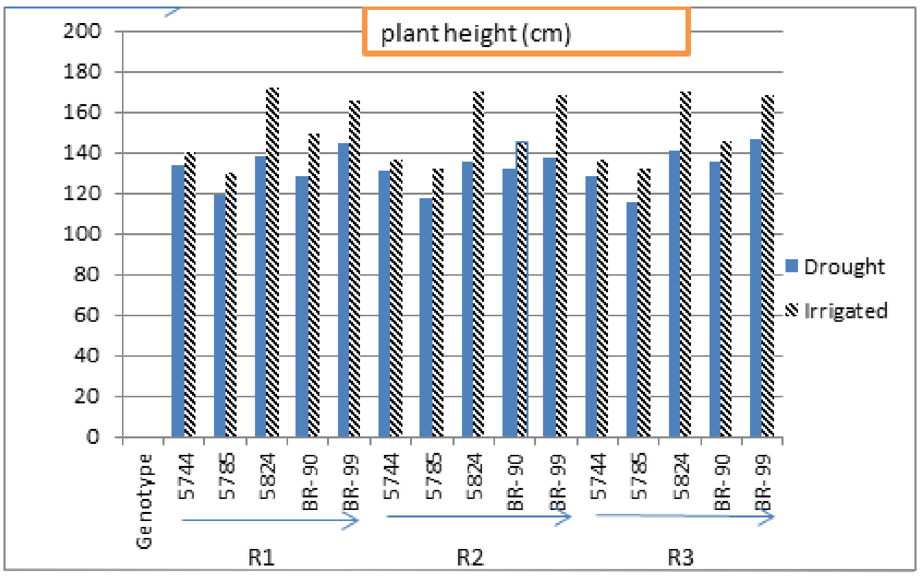

Figure 1. Comparison between drought and irrigated set for plant height (cm).

genotypes under study.

The plant height showed negative correlations with number of clusters plant^{-1} in drought (r^2=-0.23) and irrigated (r^2=-0.4385) conditions which means that as the Plant height of genotypes increases, the number of clusters plant^{-1} decreases while plant height showed positive correlation with other characters (Tables 5 and 6).

The two genotypes S-5824 and BR-99 were taller in both irrigated and drought conditions and performed well under both conditions, results are agreed with that of Ali et al. (2015), which stated that plant height of accessions BR99, BWP 5595, was less affected under water deficit conditions. On overall basis of all genotypes showed poor performance under drought conditions as compared to irrigated conditions (Figures 1 to 6).

Number of clusters plant^{-1}

The GMS for the number of clusters plant^{-1} was 29.9160 and Genotypic F value was 48.72 which showed highly significant results at 5% level of significance in drought set while in irrigated set, GMS (117.4893) and Genotypic F (2.58) showed highly significant results at 5% probability (Tables 3 and 4).

The Number of Clusters Plant^{-1} showed negative correlation with plant height (r^2=0.23), number of seeds pod^{-1} (r^2=0.5549), pod length (r^2=-0.5898) and number of seeds plant^{-1} (-0.3892) in drought set (Table 5). Under irrigated conditions number of cluster plant^{-1} had negative correlation with all characters except number of pods plant^{-1} (Table 6). The genotype BR-90 had maximum number of clusters plant^{-1} in drought set as compared to irrigated set while other four genotypes namely S-5744, S-5785, S-5824, BR-90 performed better in irrigated set and less number of clusters are formed in drought set.

Number of seeds pod^{-1}

The genotypes had highly significant differences with

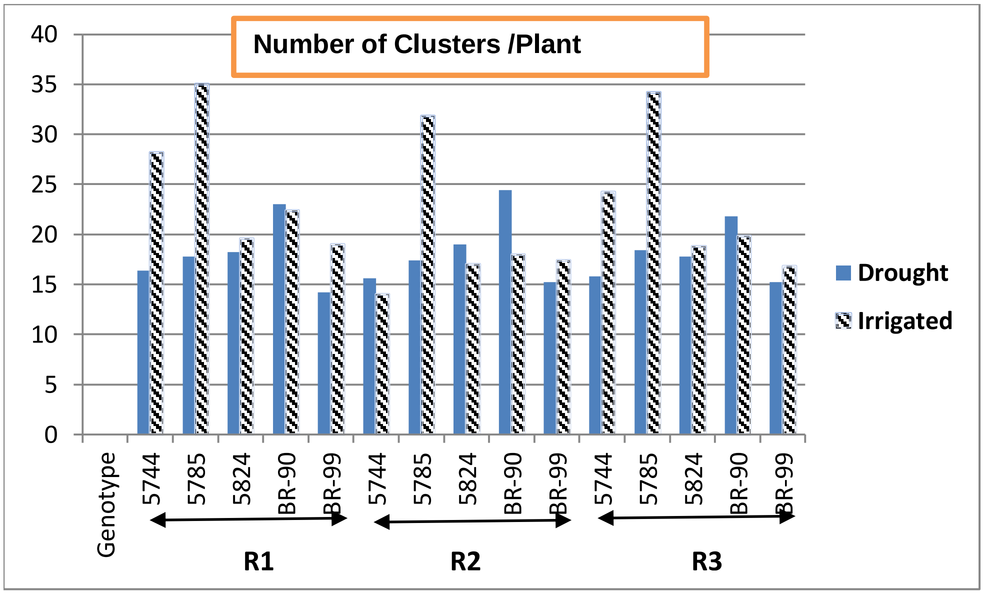

Figure 2. Comparison between drought and irrigated set for number of clusters $plant^{-1}$.

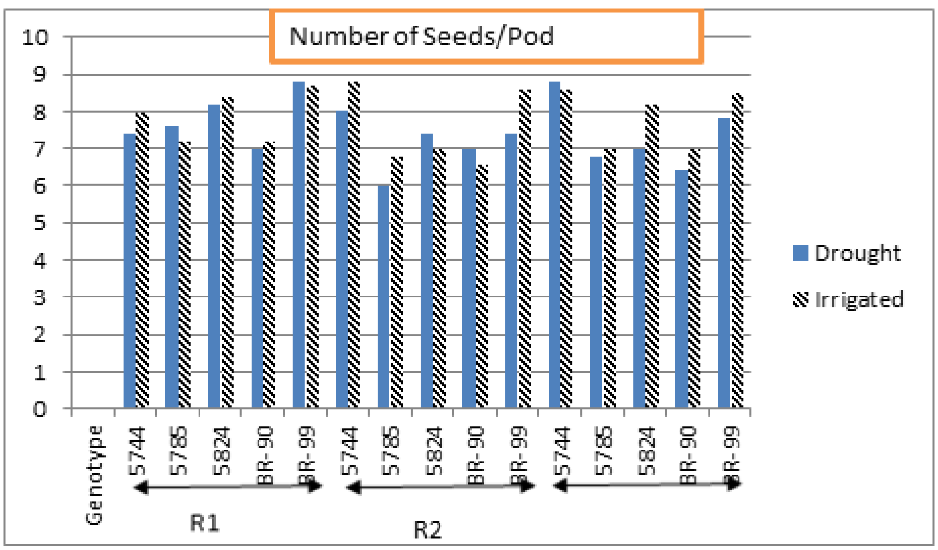

Figure 3. Comparison between drought and irrigated set for number of seeds pod^{-1}.

genotypic mean square value of (1.1507 and 873.5773) and Genotypic F value of 2.86 and 1.03 which is greater than probability value under both soil conditions, respectively (Tables 3 and 4).

The number of seeds pod^{-1} showed positive correlation with pod length (r^2= 0.9229) and number of pods per plant (r^2= 0.572) in drought set which means that an increase in pod length and number of pods $plant^{-1}$ results in increase in the number of seeds pod^{-1} (Table 5), while irrigated set number of seeds pod^{-1} showed positive correlation with other two characters as shown in Table 6. The five genotypes performed well in the number of seeds pod^{-1} in three replications, BR99, S-5785, S-5824, BR-90 and S-5744 and showed maximum number of seeds pod^{-1} in drought condition at zero irrigation which only depend on rainfall and it means that, these genotypes will perform better in highly drought conditions at high temperature.

Pod length (cm)

The genotypes showed significant results for pod length and variations presents between the genotypes because

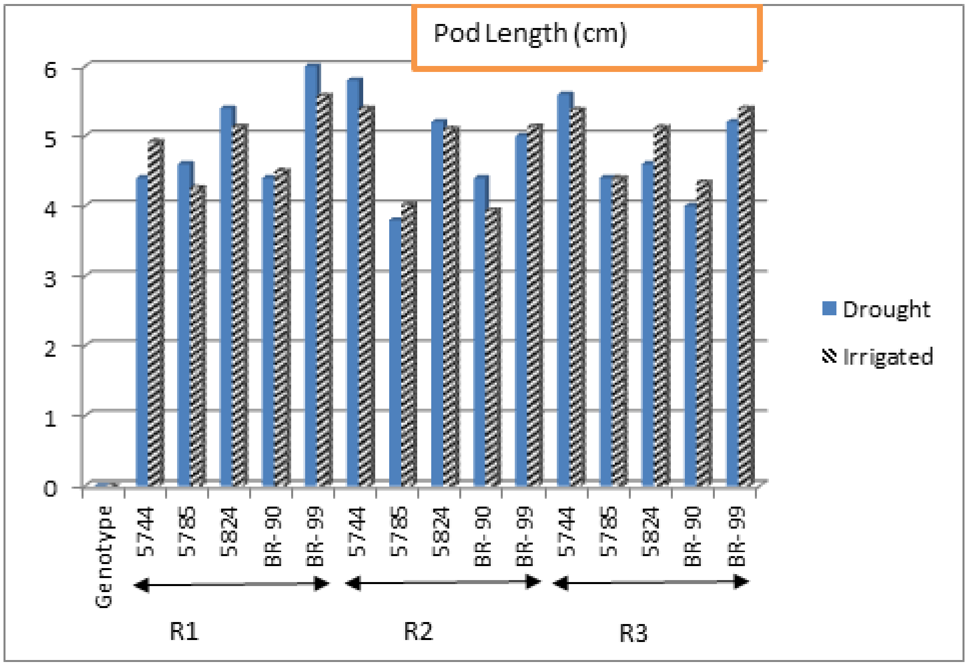

Figure 4. Comparison between drought and irrigated set for pod length (cm).

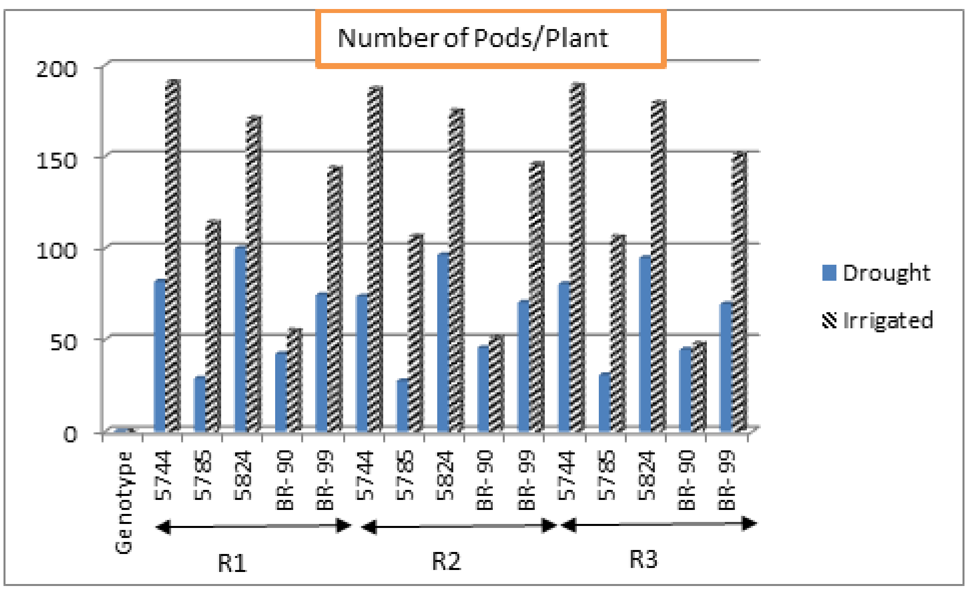

Figure 5. Comparison between drought and irrigated set for number of pods plant^{-1}.

of the significant Genotypic F value (3.00) obtained, which was greater than Probability F value in drought set (Table 3). Since the genotypes of irrigated set have highly significant results among the genotypes for pod length, variations were present in genotypes due to significant Genotypic F value 20.07 (Table 4). The positive correlation was found between pod length and number of pods plant^{-1} in drought and irrigated set (0.6331 and 0.7850) (Tables 5 and 6).

The comparison among the genotypes S-5785, S-5824, BR-99, S-5744, BR-90 performed better in drought conditions for pod length in three replications. These genotypes had the ability to perform well in drought conditions with no irrigation and depend only on rainfall.

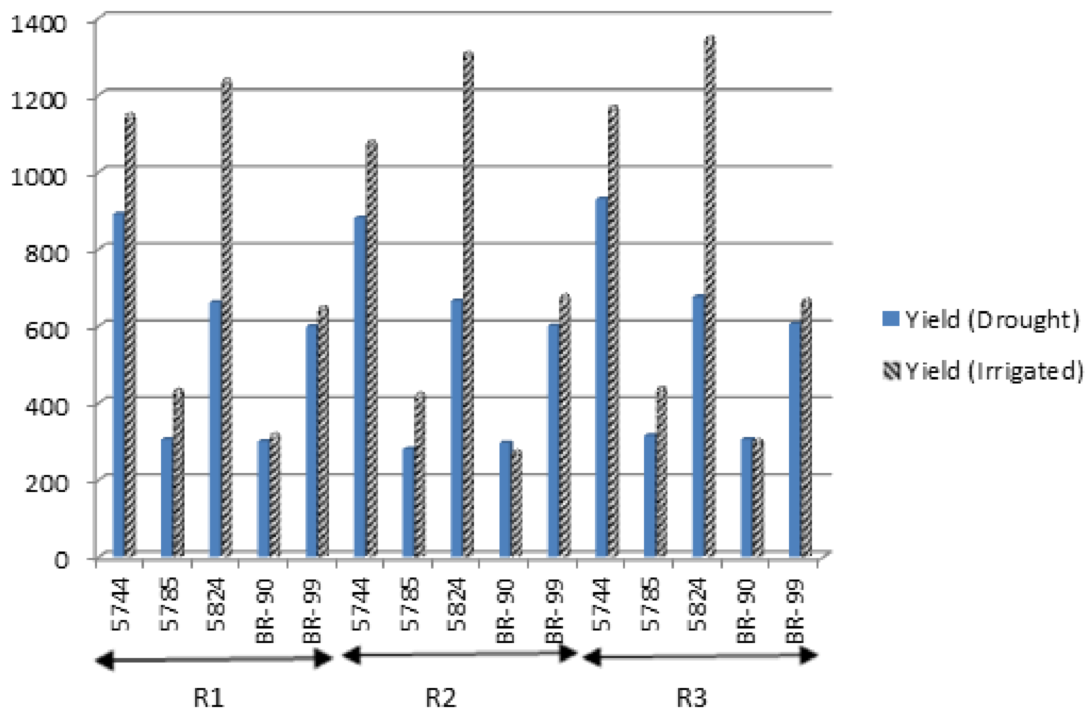

Figure 6. Comparison between drought and irrigated set for yield.

Table 3. ANOVA of five plant characters in drought set.

Trait	Replication mean square	Genotypic mean square	Error mean square	Replication F value	Genotypic F value	Probability value 5%
Plant height (cm)	10.3280	284.5507	11.6147	0.89	24.50**	0.4480 0.0002
No. of cluster plant^{-1}	0.3707	29.9160	0.6140	0.60	48.72**	0.5699 0.0000
No. of seeds pod^{-1}	0.5360	1.1507	0.4027	1.33	2.86**	0.3169 0.0964
Pod length (cm)	0.0507	0.9027	0.3007	0.17	3.00**	0.8478 0.0869
No. of pods plant^{-1}	10.0880	2233.8693	7.3313	1.38	304.70**	0.3065 0.0000
Yield (g/plot)	637.2667	197737.2667	121.0167	5.27	1633.97	0.034

Number of pods plant^{-1}

The genotypic mean square (2233.8693) and Genotypic F value (304.70) showed that, genotypes possessed highly significant and maximum variations which is a good sign for selection of better performing genotypes in drought set (Table 3). The genotypes in irrigated set also had significant results due to high value of Genotypic F (542.13), and showed more variations among the genotypes (Table 4).

Positive correlation was observed in number of Pods plant^{-1} with all other characters except the number of cluster plant^{-1} in drought conditions. Three genotypes had maximum number of pods plant^{-1} in irrigated conditions

Table 4. ANOVA of five plant characters in irrigated set.

Trait	Replication mean square	Genotypic mean square	Error mean square	Replication F value	Genotypic F value	Probability value
Plant height (cm)	803.8107	1930.6293	1106.7473	0.73	1.74**	0.5131 0.2331
No. of cluster plant^{-1}	8.8640	117.4893	45.5873	0.19	2.58**	0.8271 0.1185
No. of seeds pod^{-1}	842.2527	873.5773	847.9593	0.99	1.03**	0.4118 0.4478
Pod length (cm)	0.0593	0.9226	0.0460	1.29	20.07**	0.3269 0.0003
No. of pods plant^{-1}	4.1787	9251.6093	17.0653	0.24	542.13**	0.7885 0.0000
Yield (g/plot)	1581.6667	568333.3333	1142.0833	1.38	497.63	0.3045 0.0000

Table 5. Correlation between five plant characters in drought set.

Correlation	Plant height	No. of clusters plant^{-1}	No. seeds pod^{-1}	Pod length	No. of pods plant^{-1}
No. of clusters plant^{-1}	-0.2300	-	-	-	-
No. seeds pod^{-1}	0.4175	-0.5549	-	-	-
Pod length	0.4855	-0.5898	0.9229	-	-
No. of pods plant^{-1}	0.7079	-0.3892	0.5720	0.6331	-
Yield (g)	0.4310	-0.6252	0.6671	0.6731	0.8210

Table 6. Correlation between five plant characters in irrigated set.

Correlation	Plant height	No. of clusters plant^{-1}	No. seeds pod^{-1}	Pod length	No. of pods plant^{-1}
No. of clusters plant^{-1}	-0.4385	-	-	-	-
No. seeds pod^{-1}	0.2696	-0.7911	-	-	-
Pod length	0.4826	-0.2852	0.2289	-	-
No. of pods plant^{-1}	0.4213	0.0865	0.0894	0.7850	-
Yield	0.3665	0.1096	-0.0996	0.6944	0.9053

compared to drought conditions and the genotypes S-5744, S-5824 and BR-99 performed well in irrigated conditions which means that these genotypes are very sensitive in shortage of water and produce less number of pods plant^{-1}.

Yield (grams)

The Genotypic Mean Square (197737.2667) and Genotypic F value (1633.97) showed highly significant differences among the genotypes in drought set which illustrated the significant variation among genotypes (Table 3). The similar trend was observed for GMS (568333.3) and Genotypic F Value (497.63) in irrigated set (Table 4).

The comparison between drought and irrigated conditions for yield showed that two genotypes (S-5744 and S-5824) performed well in the drought and irrigated environment and gave maximum yield (900 and 666.67 g) in drought and (1133 and 1300 g) irrigated conditions, as compared to other genotypes (Tables 7 and 8). Yield showed positive correlation in drought conditions with all

Table 7. Five characters of genotypes in drought trial.

Characters	BR-99	BR-90	S-5744	S-5824	S-5785
Plant height (cm)	143.07	132.20	130.93	138.60	117.40
No. of clusters plant^{-1}	14.87	23.07	15.93	18.33	17.87
No. of seeds pod^{-1}	8.00	6.80	8.07	7.53	6.80
Pod length (cm)	5.40	4.27	5.27	5.07	4.27
No. of pods plant^{-1}	71.47	44.13	78.80	97.07	29.13
Yield (g/plot)	601	300	900	666.67	300

Table 8. Five characters of genotypes in irrigated trial.

Characters	BR-99	BR-90	S-5744	S-5824	S-5785
Plant height (cm)	168	147.30	137.30	172.10	129.50
No. of clusters plant^{-1}	17.73	21.13	25.80	19.73	33.67
No. of seeds pod^{-1}	8.60	6.90	8.50	8.20	7
Pod length (cm)	5.40	4.30	5.20	5.10	4.20
No. of pods plant^{-1}	146.9	51.33	189	175.1	109
Yield (g/plot)	666.67	300	1133.30	1300	433.33

characters except the number of clusters plant^{-1} which showed negative correlation while in irrigated conditions, yield possessed positive correlation except the number of seeds pod^{-1} which showed negative correlation (Tables 5 and 6).

Conclusion

From this experiment, it is concluded that two genotypes S-5744 and S-5824 performed well under drought and irrigated conditions and produced more number of seeds pod^{-1}**,** pods plant^{-1}, pod length and finally the grain yield, which means that these two genotypes were selected on the basis of graphical data and had better nutrients and water use efficiency under shortage of water and higher temperature/climatic conditions. These genotypes (S-5744 and S-5824) will be helpful for increase guar production in the country, if release for general cultivation.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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