Research Article

Evaluation and Screening of Promising Drought Tolerant Chickpea (*Cicer arietinum* L.) Genotypes Based on Physiological and Biochemical Attributes Under Drought Conditions

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Abstract | Extreme climatic conditions like heat waves, dry spell, sustained drought and precipitation adversely reducing the crop productivity and these are considered as an alarming issue for the crop production in rainfed areas. Chick pea is deemed to be regarded as a drought sensitive crop. The low water and fertilizer demand and its ability to grow on marginal land is an excellent choice for the farming community. The field trial was conducted with the aspect to screen out the drought-tolerant variety of chick pea keeping in view the physiological and biochemical attributes under drought conditions. Drought stress adversely reduced the vegetative growth in term of primary branches, secondary branches and pod yield. Based on biochemical, morphological and physiological parameters a significant difference was observed among the genotypes. Out of twenty-five genotypes, three chick pea genotypes i-e chick pea genotypes GGP1260, GGP1426 and PB01 shown the best drought tolerance efficiency (83.78, 84.21 and 81.57%), harvest index (83.23, 84.06, and 81.14%) and minimum reduction in pod yield (16.21, 15.78 and 18.42%) under rainfed controlled conditions. Under rainfed condition the activity of all enzymes increased among all genotypes. The chick pea genotypes, GGP-1260, PGP-1426 and PB-1 were observed as drought-tolerant ones on the basis of biochemical, morphological and physiological parameters and these can be recommended for rain-fed areas crop selection.

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Introduction

Drought effects are commonly related to the agriculture and water resource sectors. They may cause substantial economic losses in the agriculture sector of developed countries through reductions in crop yield or total failure of crops (Sweet et al., 2017; Tian et al., 2018). Under certain circumstances they can also cause human migration and famine in developing countries (Gray and Mueller, 2012;

Grolle, 2015). Hydrological droughts may also cause significant effects to irrigated agricultural systems (Maestro et al., 2016; Vidal-Macua et al., 2018) and problems for urban water supply, industrial needs, reductions of hydropower production, etc. (Balling and Gober, 2007; Jerez et al., 2013; Vicente-Serrano et al., 2020). At the world level, about 35% of world land having climate arid and semi-arid. In the world, the farmers have adopted low yield set of varieties for the chick pea crop sowing in rain-fed areas. The adaptation of such type of genotypes cultivation restricts the use of optimal inputs (Jackson et al., 2007). The concept of promising drought tolerance of chick pea genotypes becoming a new task for researchers in Pakistan because the current scenario of water shortage, change in climate change due to global warming as well as conversion of irrigated land into colonies adoption (Fahad et al., 2017; Eckstein et al., 2019; Jamro et al., 2020).

In Pakistan, the period of a long drought and sudden rain are the main constraints in yield reduction of chick pea crop because the climate of Pakistan mostly existing in the dry region where the water shortage is the main problem. The climate change effecting the whole world now the scenario is that the Pakistan ranked the toppest 10th of the severely affected countries (Aziz et al., 2017; Fahad et al., 2017). In Pakistan, during rabi season after the wheat chick pea is the second crop which cultivated in Pakistan. The breeding and selection of those genotypes which can grow under drought are considered an effective method to minimize the repercussion of drought exposure (Eckstein et al., 2019; Jamro et al., 2020).

Among the leguminous crops of the world, Chick pea is the 3rd leguminous grain after the dry beans and peas. In Asia, the cultivation and production of the chick pea contribute about 90%. It is also grown in the areas of West Asian and North African (WANA) Region and eastern Africa, the Mediterranean Region and North and Central America (Ali and Kumar, 2001). In Pakistan, Chick pea is considered as second rabi crop after the wheat (GOP, 2015). In Pakistan, lack of marginal land adaptation trend and recent techniques and suitable crop varieties selection are the main constraints for the formers (Vural and Karasu, 2007).

At the global level, among the leguminous crops Chick pea is the 2nd most cultivated crop which is mostly adopted by the arid and semi-arid regions farmers especially Pakistan (Maqbool et al., 2017; Varshney et al., 2014). It is mostly grown under rainfed conditions. Availability of water in rainfed regions is only possible through moisture conserving in sub-tropical areas and during heavy rainfall showers of summer. In these conditions rainfed chickpea plantations encounters the serious yield losses due to terminal drought stress (Turner et al. 2001; Shah et al. 2020). The project was held with the objectives to evaluate the performance of chick pea (*Cicera rietinum* L.) germplasm under drought and in addition to identify the suitable yielding germplasm under drought condition.

Materials and Methods

Experimental layout and location

The planned field trial conducted at Air Port campus in the Research area of Ghazi University, D.G. Khan. There were 25 genotypes which were collected from different research stations (Arid Zone Research Institute, Bhakkar, Ayub Agriculture Research Institute Faisal abad and Nuclear Institute of Agriculture and Bio technology Faisalabad, Pakistan). Three rows of each genotype were sown with 10 seeds per row. Plant - plant distance 30cm and row - row distance 45cm were maintained. Two main plots were prepared one for irrigated (well-watered) conditions and second, was nominated for rainfed (drought) condition. The design used was RCBD with factorial arrangements and three replications were used. Soil samples were taken from 15-30 cm and analyzed for the study of Physico-chemical analysis (Table 1).

Table 1: *Physico-chemical analysis of soil samples.*

Sr.	Physico-chemical characteristics	Readings
1	ECe (dS m^{-1})	2.05
2	pH	7.80
3	Bulk density (Mg m^{-3})	1.57
4	CEC (C $mol_c kg^{-1}$)	8.12
5	SAR	7.14
6	Texture	Sandy loam

Measurements and calculations

Fresh biomass of chick pea plants was recorded by using an electric balance and calculated means of each treatment. The pods of both unfertile and fertile were recorded for collection of total number of pods per plant. The branches both secondary and primary from each individual plant were recorded and summed up as number of branches per plant.

Table 2: *Effect of terminal drought on pods per plant and fresh biomass per plant (g) under rain fed and irrigated conditions.*

Genotypes	Pods per plant		Fresh biomass per plant (g)	
	Rain fed conditions (Io)	Irrigated conditions (I1)	Rain fed conditions (Io)	Irrigated conditions (I1)
PGP-1479	51± 3.87	62± 3.55	21.90± 1.89	45.3± 2.90
PGP-1426	73± 4.80	80± 3.70	39.54± 2.27	47.1± 3.17
BIC-2006	60± 4.51	77± 3.57	20.23± 1.08	43.05± 3.03
OSA-0285	62± 2.78	80± 3.45	17.6± 1.65	36.18± 2.90
OSA-005	42± 2.70	48± 2.37	22.18± 1.88	45.56± 2.94
Thal-2006	42± 2.18	55± 2.45	35.1± 2.28	71.2± 3.40
GGP-1406	58± 3.17	73± 2.60	35.46± 2.97	73.15± 3.87
GGP-1458	58± 3.22	70± 2.34	30.13± 3.03	62.23± 2.74
NLS-0613	48± 2.27	62± 2.87	27.3± 1.84	55.12± 2.57
GGP-1499	51± 2.90	66± 2.50	15.66± 1.18	31.5± 2.17
GGP-1484	46± 2.67	58± 2.47	9.96± 0.87	22.45± 1.87
GGP-1439	48± 1.79	57± 2.40	14.5± 0.87	30.35± 1.95
93A138	57± 2.27	68± 2.51	10.05± 1.07	21.43± 1.80
GGP-1419	29± 2.10	40± 1.27	9.87± 0.80	20.48± 1.84
PB-2008	58± 3.97	79± 2.85	16.54± 1.28	28.45± 1.98
06A045	42± 1.68	57± 2.34	18.22± 1.12	37.34± 2.13
GGP-1415	54± 1.74	75± 2.80	15.56± 1.13	32.25± 2.80
GGP-1260	59± 1.64	73± 2.77	35.44± 2.80	42.46± 2.90
06A09	43± 1.53	60± 1.23	20.25± 1.88	43.12± 2.85
GGP-1483	59± 1.61	80± 2.80	25.1± 1.90	53.42± 3.18
PB-1	56± 3.78	68± 1.34	44.66± 2.87	55.24± 3.25
K-70008	60± 2.87	75± 2.77	27.36± 1.97	56.67± 3.28
PB-2000	57± 2.56	73± 2.69	26.05± 2.14	54.23± 3.20
Punjab-2008	70± 3.42	84± 1.82	33.5± 2.30	49.24± 2.98
Brittle-98	54± 3.52	68± 1.32	34.7± 2.80	49.45± 2.95
Grand Mean	53.48	67.52	24.27	44.28

Data were collected before and after harvest, was carried out and data recorded on all aspects of the test entries including days to flowering initiation, branches (primary and secondary), plant height, fresh biomass per plant were measured. The method of Fischer and Maurer (1978) was followed to calculate % reduction in yield. Drought Tolerance Efficiency (DTE) and Harvest Index (HI) were calculated by Donald and Hamblin (1976) and Fischer and Wood (1981) given formulas.

$$\text{Drought Tolerance Efficiency (\%)} = \frac{\text{Yield in rainfed}}{\text{Yield in non rainfed}} \times 100 \quad \dots(1)$$

$$\text{Harvest Index (HI)} = \frac{\text{Grain Yield}}{\text{Biological Yield}} \times 100 \quad \dots(2)$$

$$\text{Percent Reduction} = \frac{\text{Yield in non rainfed} - \text{Yield in rainfed}}{\text{Yield in non rainfed}} \times 100 \quad \dots(3)$$

To evaluate the activity of different antioxidant enzymes, half a gram of fresh sample of the leaf was ground a cold ice bath in a solution of in cold PO_4 buffer solution Homogeneous mixture centrifuged at 15000rpm at the temperature of 4 °C for 20 minutes.

The activity of super oxidismutase was estimated by the nitroblue tetra zolium (NB T) photo reduction by the Giannopolitis and Ries (1977) method. The absorbance wave length was 560 nm adjusted on UV-VIS spectro photometer. Each enzyme activity and protein contents were recorded by the suggested method of Bonjoch and Tamayo (2001). The activities of POD and CAT were calculated through the method of Chance and Maehly (1955) which were estimated as a absorbance change of 0.01units in a duration of one minute at a wavelength of 240 nm and 470 nm.

Table 3: *Effect of terminal drought on primary branches and secondary branches under rain fed (Io) and irrigated (I1) condition.*

Genotypes	Primary branches		Secondary branches	
	Rain fed conditions (Io)	Irrigated conditions (I1)	Rain fed conditions (Io)	Irrigated conditions (I1)
PGP-1479	2.26± 0.38	2.33± 0.37	08.10± 1.87	10.12± 1.03
PGP-1426	3.93± 0.57	4.07± 1.27	11.60± 2.11	12.10± 1.27
BIC-2006	3.1± 0.23	3.24± 0.70	7.30± 1.65	9.38± 0.87
OSA-0285	3.08± 0.87	3.20 ± 1.75	7.50± 1.70	9.57± 0.93
OSA-005	3.72± 0.92	3.90± 1.17	7.80± 1.67	9.90± 0.84
Thal-2006	3.34± 0.85	3.42± 1.53	8.15± 1.80	10.20± 1.02
GGP-1406	3.4± 0.78	3.56± 1.17	8.25± 1.84	10.30± 1.03
GGP-1458	3.7± 0.90	3.87± 1.32	9.27± 1.89	11.30± 1.10
NLS-0613	3.85± 0.67	3.95± 1.30	9.40± 1.91	11.34± 1.08
GGP-1499	2.86± 0.60	2.90± 0.61	9.50± 1.92	11.56± 1.12
GGP-1484	3.7± 0.81	3.76± 1.23	9.75± 1.93	11.80± 1.01
GGP-1439	3.6± 0.84	3.70± 1.15	9.65± 1.80	11.67± 1.14
93A138	3.7± 0.69	3.89± 1.22	9.35± 1.66	11.41± 1.11
GGP-1419	2.87± 0.47	2.98± 0.99	8.87± 1.87	10.90± 0.97
PB-2008	2.95± 0.46	3.04± 1.07	8.90± 1.96	10.84± 1.07
06A045	2.97± 0.53	3.10± 1.43	9.20± 1.45	11.23± 1.10
GGP-1415	3.65± 1.17	3.78± 1.54	9.40± 1.50	11.34± 1.11
GGP-1260	3.11± 1.02	3.11± 1.05	10.52± 2.09	10.65± 1.02
06A09	3.82± 1.10	3.90± 1.08	9.20± 1.47	11.23± 1.00
GGP-1483	3.90± 1.12	3.98± 1.12	9.70± 1.53	11.78± 1.13
PB-1	3.53± 0.97	3.42± 1.01	11.20± 2.10	12.15± 1.17
K-70008	4.10± 1.14	4.50± 1.24	10.15± 2.07	12.2± 1.02
PB-2000	4.05± 1.10	4.33± 1.16	10.20± 2.01	12.15± 1.18
Punjab-2008	4.13± 1.07	4.26± 1.18	9.90± 1.18	11.89± 1.12
Brittle-98	4.11± 1.03	4.48± 1.20	10.20± 2.07	12.17± 1.17
Grand Mean	3.50	3.63	9.32	11.17

Statistical analysis

The differences among the treatments means was measured through statistical analysis in RCBD 2 factorial arrangement (Steel et al., 1997) by using Statistics 8.1 software.

Results and Discussion

Fresh biomass per plant (g) and pods per plant

The genotypes PGP-1426, GGP-1260 and PB-01 revealed highest fresh biomass per plant in rainfed conditions (39.54± 2.27, 35.44± 2.80 and 44.66± 2.87) and irrigated conditions (47.1± 3.17, 42.46± 2.90 and 55.24± 3.25). The genotype GGP-1406 exhibited maximum fresh biomass per plant in irrigated conditions 73.15± 3.87) while genotype PB-1 (44.66±2.87) exhibited maximum fresh biomass per plant under rainfed conditions (Table 2). Maximum pods per plant (73.0, 59.00 and 56.00) in PGP-1426, GGP-1260 and PB-01 were recorded under water rainfed condition and while in case of non-rainfed conditions similar trend also observed in case of pods per plant (80.00, 73.00 and 68.00) (Table 2).

Primary branches and secondary branches

The vegetative growth is one of the important growth stages which actually govern all phenotypic expression and grain yield. The height of plants, primary branches and secondary branches are main attributes for estimation of vegetative growth and al has a specific function. Chick pea genotypes like PGP-1426, GGP-1260 and PB-01 showed the least reduction in case of primary, secondary branches and plant height compared to remaining ones genotypes under both irrigated and rainfed conditions (Table 2). Primary branches (3.93 ± 0.57, 3.11 ± 1.02 and 3.53 ± 0.97) in rain-fed were maintained by PGP-1426, GGP-1260 and PB-01 respectively while (4.07±1.27, 3.11± 1.05 and 3.42± 1.01) under irrigated condition. In case of irrigated condition Brittle-98 showed maximum primary branches (4.48± 1.20) and Punjab-2008 gave highest primary branches (4.13± 1.07) under rainfed condition. Maximum number of secondary branches under rainfed condition (11.60± 2.11, 10.52± 2.09 and 11.20± 2.10) were recorded by PGP-1426, GGP-1260 and PB-01 respectively while secondary branches (12.10± 1.27, 10.65± 1.02 and 12.15± 1.17) were under irrigated conditions. The highest secondary branches under irrigated conditions were recorded by Brittle-98 chick pea genotype (Table 3).

Effect of antioxidant enzymes activity

The production of ROS under stress condition can be controlled by different antioxidant enzyme which can be detoxified by three enzymes i-e. SOD, POD and CAT. The enzymatic activities were determined to estimate the pant survival under stress condition.

Superoxide dismutase (SOD)

To select drought-tolerant genotypes, there are several advanced molecular techniques; one of them is the determination of SOD. The highest activity of SOD (Unit 195± 1.25 mg^{-1} protein) was observed in GGP-1406 under rain-fed condition and the minimum activity of SOD was observed in OSA-005 under irrigated conditions (Unit 100± 1.09 mg^{-1} protein) (Table 4).

Table 4: *Effect of terminal drought on SOD, POD and CAT activity activities in chick pea under rain fed and irrigated conditions.*

Genotypes	SOD activity (U mg^{-1} protein)		POD activity (U mg^{-1} protein)		CAT activity (U mg^{-1} protein)	
	Rain fed conditions (Io)	Irrigated conditions (I1)	Rain fed conditions (Io)	Irrigated onditions (I1)	Rain fed onditions (Io)	Irrigated onditions (I1)
PGP-1479	150± 4.50	145± 1.23	1.41± 0.78	1.22± 0.68	26.49± 1.18	19.38± 0.98
PGP-1426	178± 3.68	148± 2.34	2.03± 0.90	1.57± 0.38	37.53± 1.43	29.55± 0.77
BIC-2006	150± 2.68	123± 1.45	1.63± 0.23	1.37± 0.21	25.63± 1.30	15.74± 0.58
OSA-0285	150± 1.60	105± 1.34	1.68± 0.34	1.34± 0.17	30.33± 1.18	20.37± 0.90
OSA-005	154± 1.58	100± 1.09	1.43± 0.29	1.23± 0.05	39.45± 1.18	34.74± 0.88
Thal-2006	162± 1.08	112± 1.12	1.37± 0.45	1.26± 0.18	38.11± 1.10	32.29± 0.56
GGP-1406	195± 1.25	175± 1.21	1.49± 0.59	1.33± 0.28	39.33± 1.08	29.45± 0.68
GGP-1458	177± 2.38	127± 1.38	1.46± 0.73	1.39± 0.20	34.07± 1.70	30.44± 0.75
NLS-0613	145± 2.48	115± 1.54	1.85± 0.84	1.73± 0.03	33.96± 2.78	23.91± 0.70
GGP-1499	153± 1.88	117± 1.21	1.73± 0.88	1.68± 0.04	36.29± 2.80	26.28± 0.84
GGP-1484	133± 1.34	120± 1.68	1.92± 0.08	1.77± 0.02	30.78± 2.71	20.52± 0.78
GGP-1439	117± 1.67	115± 1.82	1.98± 0.38	1.94± 0.21	29.60± 1.70	19.27± 0.56
93A138	138± 1.78	104± 1.90	1.41± 0.54	1.22± 0.78	33.78± 1.54	23.45± 0.66
GGP-1419	155± 1.50	115± 1.93	1.43± 0.50	1.27± 0.21	36.75± 1.50	26.78± 0.67
PB-2008	174± 1.56	163± 1.60	1.63± 0.68	1.37± 0.18	30.25± 1.78	27.25± 0.34
06A045	133± 1.45	113± 1.45	1.68± 0.18	1.34± 0.13	33.75± 2.23	31.50± 0.45
GGP-1415	155± 1.76	145± 1.23	1.43± 0.08	1.23± 0.04	37.00± 2.05	29.21± 0.67
GGP-1260	179± 1.77	129± 1.14	2.17± 0.18	1.56± 0.23	41.25± 1.78	31.25± 0.70
06A09	140± 1.59	133± 1.29	1.49± 0.10	1.33± 0.21	32.75± 2.15	29.25± 0.68
GGP-1483	144± 1.23	107± 1.16	1.46± 0.68	1.39± 0.34	33.27± 2.12	25.43± 0.36
PB-1	190± 2.68	119± 1.10	2.15± 0.23	1.93± 0.78	38.05± 1.78	30.50± 0.30
K-70008	139± 3.38	128± 2.08	1.73± 0.60	1.68± 0.78	30.35± 1.90	29.75± 0.45
PB-2000	120± 1.05	107± 2.00	1.92± 0.20	1.77± 058	32.56± 1.58	28.25± 0.50
Punjab-2008	160± 1.23	127± 1.18	1.98± 0.16	1.94± 0.98	29.50± 1.08	27.75± 0.63
Brittle-98	150± 1.20	141± 1.13	1.44± 0.06	1.46± 0.23	32.32± 0.78	29.13± 0.65
Grand Mean	154.08	125.32	1.676	1.49	33.84	26.84

Peroxidase (POD)

The maximum POD enzyme quantity obtained under drought rainfed condition (Unit 2.17± 0.18 mg^{-1} protein) by GGP-1260 under rainfed conditions and the lowest POD enzyme activity of the enzyme found in PGP-1479 under irrigated conditions (Unit 1.22± 0.68 mg^{-1} protein) (Table 4).

Catalase (CAT)

CAT has a role in the decomposition of peroxidase under environmental rainfed condition and plant tolerance to the rain-fed. Under rainfed condition, maximum CAT activity (Unit 41.25± 1.78 mg^{-1} protein) was observed by GGP-1260 and under irrigated condition; BIC-2006 (Unit 15.74± 0.58 mg^{-1} protein) had the lowest CAT enzyme activity (Table 4).

Drought tolerance efficiency, harvest index and percent reduction yield

Among the all genotypes, the best efficiency of drought tolerant was observed in three chick pea genotypes i-e GGP1260 (83.78), PGP1426 (84.21) andPB-01 and (81.58± 1.23%) respectively, good harvest index (84.07± 3.89, 83.24± 2.68 and 81.15± 0.68%) and minimum reduction in seed yield (15.79± 1.61, 16.22± 0.78 and 18.42± 1.04%) in rainfed environment (Table 5).

The fresh biomass of all chick pea genotypes decreased under rainfed condition. The fresh biomass of plant was dependent on genotypic makeup of chick pea genotypes as some genotypes gave more root fresh and dry weight under rainfed conditions rather than other chick pea genotypes. The dry matter production or yield development rate reduced under rain-fed conditions and also under over irrigated conditions. It may be because of the reasons that under rainfed water shortage diminished the rate of photosynthetic tracked by hindering the fertilization hindrance and shedding of the flower. Similar findings were also observed (Waqas et al., 2019; Sharma et al., 2020). In the case of irrigated conditions, less pod number observed due to more vegetative growth as a result of less light penetration and air circulation (Shan and Wang, 2017; Farooq et al., 2018). These discoveries are similar to the findings of Shrafi et al. (2014) as they observed in case of dry matter accumulation and growth rate of crop. It might be because of lacking dissolvable for photosynthetic and metabolic exercises. The production of seed and pod are also dependent on the number of secondary branches in chickpea which was significant. Moucheshi et al. (2011) also reported similar observations under drought conditions. A reduction in seed yield of 26.2% in chickpea crop was also observed under the conditions of rainfed by other researchers (Anjum et al., 2011; Walter et al., 2013; Tabassum et al., 2017).

Table 5: *Effect of terminal drought on drought tolerance efficiency, good harvest index and minimum reduction in seed yield under rain fed condition.*

Genotypes	Drought tolerance efficiency (%)	Harvest index (%)	Reduction in seed yield (%)
PGP-1479	74.29± 2.68	59.65± 2.68	25.71± 1.28
PGP-1426	84.21± 1.60	84.07± 3.89	15.79± 1.61
BIC-2006	80.56± 1.38	62.28± 1.80	19.44± 1.12
OSA-0285	82.86± 1.37	65.47± 1.28	17.14± 1.10
OSA-005	78.79± 1.28	61.33± 1.08	21.21± 1.18
Thal-2006	75.00± 3.68	57.27± 2.07	25.00± 0.98
GGP-1406	77.14± 3.70	57.75± 1.28	22.86± 1.04
GGP-1458	80.56± 3.54	60.20± 1.34	19.44± 1.18
NLS-0613	76.47± 2.80	59.81± 1.23	23.53± 1.05
GGP-1499	83.87± 3.39	66.66± 1.10	16.13± 1.09
GGP-1484	72.73± 2.68	61.24± 1.18	27.27± 1.77
GGP-1439	74.29± 1.60	61.97± 1.08	25.71± 1.65
93A138	80.00± 2.00	67.43± 1.68	20.00± 1.54
GGP-1419	78.79± 2.13	67.07± 1.56	21.21± 1.50
PB-2008	77.14± 2.00	68.62± 1.36	22.86± 1.67
06A045	73.33± 1.56	59.73± 1.09	26.67± 1.45
GGP-1415	77.78± 1.57	63.82± 1.63	22.22± 1.40
GGP-1260	83.78± 1.49	83.24± 2.68	16.22± 0.78
06A09	74.29± 1.34	59.20± 1.18	25.71± 1.60
GGP-1483	80.56± 1.60	60.50± 1.78	19.44± 1.06
PB-1	81.58± 1.23	81.15± 0.68	18.42± 1.04
K-70008	81.08± 1.12	61.24± 1.60	18.92± 1.10
PB-2000	83.33± 2.34	62.12± 1.56	16.67± 1.14
Punjab-2008	82.86± 2.68	74.19± 1.77	17.14± 1.03
Brittle-98	81.08± 2.70	74.84± 1.34	18.92± 1.00
Grand Mean	79.05	65.63	20.95

The enhancement of SOD activity in drought-tolerant cultivar of chick pea was also reported by some other researchers (Subbarao et al., 2013; Gupta, 2016; Farooq et al., 2018). Besides, Zandalinas et al. (2017) also observed that SOD lead to higher protection against drought conditions. SOD activity scavenge the toxic radicles like superoxide, hydrogen peroxide and then convert them into water and oxygen through the further activity of POD, CAT and APX which were tolerant (Patel and Hemantaranjan, 2012; Kadkhodaie et al., 2014; Dalvi et al., 2018). Sensitive genotypes showed less increment was observed superoxidismutase activity under drought conditions which develop as a result of low water potential of the cultivar to remove superoxide. The SOD over expression compensated by the highest scavenging system of hydrogen peroxide like catalase and peroxidase enzyme activities which is a better tool for anti-drought mechanism to compete for stress under conditions of drought (Raheleh et al., 2012; Oberoi et al., 2014).

In the case of chick pea crop, the activity of peroxidase is also observed by (Mafakheri et al., 2011; Kaur et al., 2013; Khadraji et al., 2016). According to their findings, higher concentration of ascorbic acid is minimized by the activity of peroxidase which function as a defensive system for the plant. Similar finding was also observed by Fan et al . (2017) in the cucumber leaves. Peroxidase scavenges hydrogen per oxide which actually produced from peroxide dismutation and catalyzed by superoxidismutase as observed in *Phaseolusvulgaris* and *Phaseolusacutifolius* (Turkan et al., 2005; Raheleh et al., 2012; Meena et al., 2014). Increase in peroxidase activity under drought condition has also been reported by (Patel and Hemantaranjan, 2012; Singh et al., 2012; Wu et al., 2014) in chickpea.

Hydrogen peroxide scavenge hydrogen peroxide and form water and oxygen reported. Enhancement was observed in the activity of Catalase in tolerant chickpea genotypes compared to susceptible genotypes (Raheleh et al., 2012). Maximum activity of catalase in tolerant faba bean also reported by Abid et al. (2016), in Green gram, Rambabu et al. (2016) and *Phaseolus vulgaris* L. by Kusvura and Dasgan (2017). In the light of current findings, it is concluded that under rainfed condition the activity of all enzymes increased among the all genotypes GGP-1260, PGP-1426 and PB-1 are considered as tolerant ones.

A lesser reduction was observed in morpho-physiological attributes and maintenance in yield stability by PGP-1426, GGP-1260 and PB-01 chick pea genotypes in rain-fed as well as irrigated condition. All these attributes result into minimum drought susceptible index and yield reduction. In contrast, maximum drought tolerance efficiency which are in line with the consideration of Ouji et al. (2016) as they reported that very low values of membrane injury index and highest harvest index in irrigated conditions as well as rain-fed condition. Similar observations were also observed by Khoiwal et al. (2017). They also concluded that the tolerant genotype of chick pea maintained highest harvest index, minimum reduction in seed yield and having maximum efficiency and minimum susceptibility index of drought under rainfed condition.

Conclusions and Recommendations

The higher production of fresh biomass and pod yield among the morphological feature, the highest activity of CAT, POD and SOD among the biochemical attributes and minimum reduction in seed yield, maximum DTE, minimum DSI and highest HI under rainfed conditions by chick pea genotypes (PGP-1426, GGP-1260 and PB-01) as compared to the other genotypes are the best indicator for the drought tolerance efficiency criteria for the mentioned chick pea genotypes. Based on these results, it was concluded that the chick pea genotypes i-e GGP-1260, PGP-1426 and PB-01 is the most drought tolerance chick pea genotypes and these can yield well under drought or rainfed condition as that have the capability to grow and generate well. Furthermore, the results from this research depict that adaptation of these screened out drought-tolerant chick pea genotypes improve the economy of farmer community especially the farmer of the rainfed area.

Author's Contribution

Muhammad Jan conceived the ideas of research and conducted experiment. Tanveer ul Haq helped in management of article. Hina Sattar worked for language improvement of manuscript. Madiha Butt helped in analysis of data. Abdul Khaliq prepared first draft. Muhammad Arif provided technical input. Abdul Rauf helped for manuscript improvement.

Conflict of interest

The authors have declared no conflict of interest.

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