Drought tolerance of some cowpea genotypes under Upper Egypt conditions

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Abstract: Yield characteristics had a significant role in determining the elite genotypes, which applied by plant breeder, this purpose relies on the method of genotypes by environments and stability behavior of genotypes. Two field experiments conducted in 2014 and 2015 amid to screening twelve cowpea genotypes for drought tolerance over 6 environments (the mixes of three interval irrigation water i.e., 6, 12 and 18 days, with two years). Combined analysis of variance revealed that highly significant ($P < 0.01$) for CHC, FD, NB, TYS, PH, PL, W100S, and PRO. Under stress conditions (D3), a great diminishing detected for TSY by 38.84% as differentiated with (D1) non-stress conditions. CHC, NB, PH, PL, and W100S decreased by 20.21, 33.46, 32.52 and 23.38 respectively, in stress conditions. While the genotypes had priority for DF by 5.38 days in stress condition, proline accumulation expanded in adverse condition by 42.44%. The genotypes No. 7, 8, 10 and 11 were stable (bi < 1), with mean values greater than the grand mean. While genotypes 2 and 4 were unstable (bi > 1) with low mean values for TSY. Genotypes No. 5, 6, 7, 8, 9, 10 and 11 were drought tolerance (SSI values < 1). as for TOL, genotypes 5, 12, 10 and 7 were drought tolerant. For STI the most desirable genotypes were 1, 8 and 9. Genotypes No. 7, 8, 9, 10 and 11 were the highest for TSY in adverse environments.
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Abbreviations: PH, Plant height; **NB**, Number of branches per plant; **FD**, Flowering date; **CHC**, Chlorophyll content; **PROC**, Proline Content; **PL**, Pod Length; **W100S**, Weight of 100 seeds; and **TSY** Total seed yield per plant.

1. Introduction

Climate changes have a certain risk over the world countries, included Egypt, because of a shortage of water and excessive heat temperature. Water stress reduced the growth and yield of cowpea. Similarly, decreasing chlorophyll content and ion ratio in leaves and grains. (Farouk and Amany, 2011). Cowpea (*Vigna unguiculata* L. Walp) regarded as a major pulse crop amongst the vegetable legumes that existing at West Africa. Further, belongs to Fabaceae family, and had a little seedling establishment and growth duration. (Chiulele, 2010). In Egypt, cowpea is grown on 14,830 feddan with production 17248 tons with (an average yield of 1.163 ton/feddan). (fed=4200 m^2), according to the Agricultural economic bulletin, 2013.

Drought at early growth stage caused many morphological changes like atrophy of leaves, limiting plant height, a number of leaves and leaf area. likewise, deferred the yield because of their influence on blossom buds and flowering stage. (Boyer, 1982). Seed yield of plants reduced at seed filling stage consequence of drought stress. (Ehdaie and Shakiba, 1996). The drought resistance defined by (Hall, 1993) as the relevant yield of genotype compared with various genotypes exposed to a similar drought condition. Drought resistance in plants might due to their potential to hold a significant amount of inner water under shortage conditions. (Keim and Kronstad, 1981). The drought mechanism in higher plants depends on their capability to escape from injury through earliness the yield (Clarke *et al.*, 1984). Expanding occurrence of water deficiency among abiotic factor is due to climate changes impacts, which prompt to diminished of crop production and might be due to decimated yields. In favorable conditions, indeterminate cowpea cultivars continue producing flowers for a long period this might be due to increased grains production. Plant breeders all over the world, especially in developing countries, do their best in developing and improved drought-tolerant cowpea cultivars, the occurrence of drought in growth and yield stage have a negatively effects on cowpea production. (Sanda and Maina, 2013). The performance of seed yield and stability of cowpea genotypes under unfavorable environments was studied by (El-Shaieny, *et al.,* 2015). The results indicated that the genotype TVU 21, Blackeye Crowder, Black Crowder and Azmerly were stable with high mean values. On the country, the genotype Chinese red was unstable with low mean values.(Hussein, *et al.,* 2014) reported that plant height, the number of leaves, fresh weight of stem and whole plant were decreased dramatically by application cowpea to water deficit by withholding water at 35 and 70 days from sowing date. GE interaction is considered important as imperative to identifying the perfect technique of breeding strategy for relapsing genotypes with high adequate adaptation to target environments. (Romagosa and Fox, 1993). Previous studies indicated that stability parameters in pulse crops have been done to estimate phenotypic stability (Arshad *et al.,* 2003 and Cakmakci *et al.,* 2006 and El-Shaieny, *et al.,* 2015). Proline accumulation may be due to inhibition of protein synthesis and its associated with osmotic adjustments. (Beebe, *et al.,* 2008). Proline accumulation is considered one of the various biochemical causes of water stress. These results were found in many wild and cultivated plants (Ashraf and Iram, 2005). Therefore, this study was designed to assess some cowpea varieties for yield and some traits related to drought stress, with the measuring of relative stability of these genotypes under different environments.

2. Materials and Methods

Field experiments conducted at the experimental farm, Faculty of Agriculture, South Valley University, Egypt during the growing seasons of 2014 and 2015 summer season. Twelve cowpea genotypes, (*Vigna unguiculata* L. Walp), assessed under drought stress conditions. Theses genotypes were Dokii 331, IT81D1032, TVU 21, IT82D-812, IT81D1064, IT82D-889, IT91K118-20, Monarch Blackeye, Azmerly, IT93K2045-20, IT85F2205, and IT90K1020-6. The twelve genotypes exposed to three irrigation intervals 6 (D1), 12(D2) and 18(D3) days, where the (D1) is favorable conditions and the (D3) which unfavorable conditions and allow the plants subjected to drought stress.

Experiment Layout and Experimental design.

Each genotype represented by experimental unit 3 × 3.5 m and repeated three times, the long of the row was 3m, 60 cm apart and plants spaced 20 cm from each other. The experiments were planted on March 13th and 15th in the summer seasons of 2014 and 2015. A spilt plot design with three replicates was done. The irrigation treatment and genotypes were randomly allocated to the main plot and subplots, respectively. Then, different agricultural production practices i.e. fertilization and pest management were applied as commercial cowpea production.

Measurements:

1. Plant height, PH. (cm).
2. Number of branches per plant, NB.
3. Flowering date, FD.
4. Chlorophyll content, CHC.
5. Proline Content, PROC.
6. Pod Length, PL. (cm).
7. Weight of 100 seeds, W100S.
8. Total seed yield per plant, TSY.

Quantitative indicators of drought tolerance calculated as follow:

Tolerance index (TOL) estimated according to (Rosielle and Hamblin 1981) as follow: TOL= (YP - YS). Where: YP= yield potential, YS= stress yield.

Stress susceptibility index (SSI) measured according to (Fisher and Maurer 1978): SSI= 1-(YS/YP)/SI. SI= (YS /YP) where SI is stress intensity.

YS= mean yield in the stress environment. While YP= mean yield in a non-stress environment.

Geometric mean productivity (GMP) calculated according to (Fernandez, 1992; Kristin *et al.,*1997): GMP= (YP) (YS).

Stress tolerance index (STI) estimated according to (Fernandez, 1992; Kristin *et al.,*1997): STI= (YP) × (YS)/ (YP)^2.

Stability analysis:

Stability parameters for studied traits of twelve genotypes of cowpea computed as described by (Eberhart and Russell, 1966).

Data analysis:

The analysis of variance performed according to (Gomez and Gomez 1984). Least significant differences (LSD) used for comparing means.

3. Results and Discussion

The performance of cowpea genotypes under drought stress.

Analysis of variance confirmed that presence of genetic variability among cowpea genotypes was highly significant. irrigation water treatment showed the similar effect for CHC, NB, FD, TSY, PH, PL, W100S, and PROC Table 1. An extremely significant ($P < 0.01$) G × Y interaction detected in the traits of FD, NB, PH, W100s, PL and PROC. While, G × I interaction obtained with CHC, NB, TYS, PH, PL, and PROC. the following order interactions (G× I×Y) was highly significant ($P<0.01$) for CHC, NB, TSY, PL, and PROC. these findings indicate that cowpea genotypes responded diversely to different environments, suggesting the screening of cultivars under varied environments are viewed as the most favorable method of genetic makeup for a specific environment.

These outcomes are in accordance with those mentioned by Cholin, *et al.* (2010). Al-Ameen (2012), Ceyhan *et al.* (2012), (2015), El-Dakkak *et al.* (2015), El-Shaieny *et al.* (2015) and Aliyu and Makinde (2016). The data in Table 2 illustrate that (D3) treatment led to significant decrease in TSY, W100S, NB, CHC and PH by 38.84, 10.73, 33.46 20.21 and 32.52 respectively, as compared with (D1). While FD was earlier by 5 days in stress conditions. These outcomes are agreed to with those obtained by Kheiralla, and Ismail (1995) and Kheiralla, *et al.* (1997) and Al Ameen (2012) on wheat. Farouk, and Amany. (2011) and Hussein *et al.* (2014), Hussien and Abd El-Hady (2015) on cowpea,. The mean values of environments for PH ranged from 44.45 to 72.34 cm, for NB run from 3.04 to 4.56, FD from 59.17 to 62.58, CHC from 61.63 to 78.56, concerning PROC from 3.82 to 6.57, PL from 10.51 to 14.21, for W100S from 14.47 to 16.03 and for TSY from 20.57 to 33.54. find in Table 3 These results showing that there were different environmental variation observed. On the other side, TSY and W100S displayed in Table 4 which extended from 12.58 and 12.09 for IT81D1064 to 52.13 and 18.33 g for Dokii 331 genotype under favorable and unfavorable conditions, respectively.

Proline and chlorophyll content as affected by drought.

CHC for genotypes ranged from 69.25 for IT91K118-20 to 87.14 for IT85F2205 genotype under favorable conditions and from 55.12 for Dokii 331 to 67.17 for IT81D1064 genotype under drought condition. As for Proline content, the genotype IT85F2205 gave the highest value of proline content (6.10 and 9.50), while, IT81D1064 gave the lowest value (2.83 and 5.29) under favorable and unfavorable environments respectively.

Drought stress indicators.

Data presented in Table 5 and Fig. 1 and 2 illustrated that the genotypes IT93K2045-20, IT91K118-20, IT81D1064, and IT82D889 had a rough estimate of TOL and SSI and showed the greatest insignificant differences in TSY and W100S under both environments favorable and unfavorable. These genotypes could identify as drought tolerant genotypes and suitable for poor conditions. Also, Dokii 331, Monarch Blackeye and TVU 21 considered the superior drought tolerance genotypes with high values of STI and TSY and W100S. Similar genotypes identified drought resistance according to GMP.

Stability parameters.

The joint regression analysis in Table 6 showed that presence of genetic variability between genotypes and environment for all studied traits. GE interactions were highly significant for all studied traits. Data in Table 5 indicate that the regression coefficient (bi) values of the examined traits used in this investigations extended from 0.347 to 1.411 for CHC, 0.332 to1.720 for DTF, 0.715 to 1.879 for NB, 0.282 to 1.718 for TSY, 0.460 to 2.652 for PH, 0.789 to 1.255 for PL, 0.579 to 1.454 for W100S and 0.851 to 1.223 for PROC. These outcomes suggested that the genotypes reacted to the different environments, results to variation in the bi norm. Sharma *et al.* (1987).

Variation among environments perceived as one principle considers and had considerable impacts on (bi) values. Pfahler and Lins Kens (1979). The data illustrated that there were significant environmental changes, these might be due to a massive difference among environments that all the sufficiently better for bi estimations. Kheiralla *et al.*(1997). Concerning CHC the genotypes IT82D-812, IT81D1064, IT82D-889, IT91K118-20, and Azmerly were stable which had (bi < 1), considered more desirable and adjusted for unfavorable conditions. IT81D1064 has a high mean performance and S2d not significant and closes to zero (Table 7). genotypes IT81D1032 and IT81D1064 were stable since it has a high mean performance, regression coefficient (bi< 1) and significantly, S2d from the unit for FD character. IT82D-812 and IT85F2205 genotypes appeared below stability average (b= 1.316 and 1.172), explaining that these genotypes execution was well in common conditions (D1). The best NB was showing by the genotypes IT81D1032 and IT91K118-20 presented in Table 6. Regarding TSY, the regression coefficients bi for all genotypes differed significantly from unity and the deviation from regression S2d was significant for most of these genotypes. Hence, based on an estimate of stability these genotypes are unstable for TSY as indicated by (Finlay and Wilkinson, 1963), Monarch Blackeye and TVU 21 showed little S2d values and were not significant. Dokii 331 and Azmerly had a high mean performance for TSY with below stability average (1.718 and 1.383), showing that these genotypes performed well under suitable environments showed by data in Table 7 that all genotypes viewed as unstable for PH trait. affirming that these genotypes elite and extreme sensitivity to change environments. Dokii 331, IT93K2045-20 and IT85F2205 were stable for PL, and it gave the high mean and considered stable (bi< 1) and S2d were insignificant. While The genotypes Dokii 331 consider superior, because it has the tallest PL beside it was stable similar results observed by Rashwan 2010, El-Dakkak 2015. The results for W100S in Table 6. IT81D1032 and Monarch Blackeye considered adjusted for drought conditions since it has high mean with bi< 1 and S2d were insignificant. While, Dokii 331, IT81D1032, IT82D-812, and IT82D-889 genotypes having bi non-significant from unity and S2d insignificant from zero for PROC. Dokii 331 considered prevalent and adjusted for poor environments.

Table 1 The combined analysis of variance for studied traits of cowpea genotypes as affected by drought conditions over two seasons.

Source of Variance	d.f	Mean Squares							
		PH	NB	FD	CHC	PROC	PL	W100S	TSY
Year (Y)	1	936.709**	1.318**	29.011**	55.298**	0.267**	3.393**	3.614	0.479
R/Y	4	5.961	0.376	0.467	2.769	0.775	11.010	1.889	6.387
Irrigation (I)	2	9966.049**	41.017**	218.759**	4409.869**	138.906**	201.361**	66.530**	3091.691**
I × Y	2	255.029**	0.762**	90.299**	36.010**	0.014	6.178**	13.649*	0.407
Error a	8	9.124	0.118	2.019	2.058	0.004	0.888	2.965	0.368
Genotypes (G)	11	21718.737**	5.498**	1243.672**	345.744**	25.159**	72.931**	139.216**	1539.023**
G × Y	11	113.846**	0.275**	11.966**	11.620*	0.001**	4.299**	1.562**	1.829
G × I	22	462.062**	0.582**	6.991	76.308**	0.322**	2.672**	0.880	62.946**
G × I ×Y	22	64.671**	0.290**	7.562*	23.372**	0.003**	1.777**	0.933	0.216**
Error b	132	3.289	0.125	4.471	6.142	0.069	1.000	0.718	1.004

- $P < 0.05$ and ** $P < 0.01$

Table 2: Means of PH, NB, FD, PROC, CHC, PL, TSY and W100S under drought conditions over two seasons.

Treatment	PH	NB	FD	PROC	CHC	PL	W100S	TSY
D1	72.02	4.40	61.67	3.77	77.24	14.01	15.75	33.69
D2	58.38	3.38	60.98	5.15	70.44	11.78	14.11	26.57
D3	48.60	2.93	58.35	6.55	61.63	10.74	14.06	20.61
L.S.D 05%	1.61	0.13	0.55	0.05	0.55	0.36	0.66	0.23
Reduction %	32.52	33.46	5.38	57.56	20.21	23.38	10.73	38.84

Table 3: Means of PH, NB, FD, PROC, CHC, PL, TSY and W100S under drought conditions over two seasons.

Genotypes	PH						NB						FD					
	E1	E2	E3	E4	E5	E6	E1	E2	E3	E4	E5	E6	E1	E2	E3	E4	E5	E6
1	62.60	55.49	47.14	59.77	47.70	38.84	3.83	2.88	2.23	4.33	3.33	2.10	48.67	44.67	43.33	47.33	47.33	45.33
2	29.06	19.39	17.76	29.50	19.52	18.22	4.45	3.67	3.03	4.67	3.75	3.43	75.38	72.26	70.71	70.44	72.66	69.47
3	93.77	85.74	80.27	89.70	70.99	55.70	3.00	2.65	2.12	3.67	2.67	2.10	58.00	58.67	55.33	56.33	58.00	58.33
4	172.87	134.68	105.47	172.38	133.05	106.45	4.38	3.75	3.18	4.33	2.33	3.43	66.17	62.33	60.00	65.12	61.33	64.12
5	60.67	54.36	50.73	60.80	47.52	37.55	3.93	3.45	3.08	4.33	3.33	3.10	66.00	65.33	61.00	67.33	70.00	64.66
6	55.13	48.05	43.02	55.17	71.51	34.06	6.75	4.65	3.44	6.33	4.00	4.10	50.63	48.00	46.33	50.33	51.00	49.33
7	40.57	33.27	28.20	40.90	24.64	25.26	4.52	3.86	3.03	4.62	4.33	3.72	59.33	53.33	50.86	50.19	57.33	49.19
8	40.27	36.58	28.85	40.50	31.26	25.15	3.67	3.25	3.00	5.00	3.25	3.10	62.67	58.66	57.00	60.00	62.00	56.00
9	135.00	101.32	93.67	134.23	103.79	83.59	3.33	3.00	2.25	4.33	3.00	2.43	76.33	73.33	72.00	76.33	75.33	71.00
10	54.23	47.09	38.37	55.11	36.64	34.03	4.37	2.91	2.25	4.43	3.00	2.53	59.56	57.33	54.66	59.96	57.00	58.96
11	36.27	29.52	24.54	35.68	24.22	22.03	4.41	3.68	3.15	4.50	3.85	3.20	65.22	62.67	60.67	64.11	68.00	63.11
12	87.58	77.58	73.85	86.82	67.10	53.61	4.30	3.28	3.00	4.17	3.27	3.27	62.96	60.33	58.33	61.58	65.33	60.58
Average	72.34	60.26	52.66	71.71	56.50	44.54	4.25	3.42	2.81	4.56	3.34	3.04	62.58	59.74	57.52	60.75	62.11	59.17
Grand Mean	59.6						3.57						60.31					
CV%	3.04						9.90						3.51					

E1= irrigation intervals 6 days, season 2014 E2= irrigation intervals 12 days, season 2014 E3= irrigation intervals 18 days, season 2014

E4= irrigation intervals 6 days, season 2015 E5= irrigation intervals 12 days, season 2015 E6= irrigation intervals 18 days, season 2015

Continue Table 3:

Genotypes	CHC						PROC						PL					
	E1	E2	E3	E4	E5	E6	E1	E2	E3	E4	E5	E6	E1	E2	E3	E4	E5	E6
1	74.26	68.46	53.82	76.27	63.96	56.41	4.03	5.26	6.4	4.16	5.3	6.51	14.10	12.59	11.66	14.80	10.42	11.91
2	86.66	77.94	66.65	79.15	77.00	61.69	3.22	4.45	5.68	3.36	4.53	5.70	12.33	11.54	10.47	12.17	11.01	8.40
3	73.69	64.10	54.65	71.77	64.33	52.24	3.32	4.55	5.78	3.45	4.63	5.80	18.43	15.69	14.43	20.13	14.86	16.34
4	73.17	66.87	59.20	73.52	66.20	56.06	3.04	4.27	5.51	3.21	4.35	5.53	13.66	12.15	10.25	13.92	9.69	10.06
5	73.07	70.93	67.37	72.00	70.30	66.97	2.82	4.05	5.28	2.93	4.13	5.30	15.20	14.04	13.78	14.97	10.17	11.02
6	77.38	73.07	69.00	70.48	75.56	63.02	2.86	4.09	5.32	2.98	4.17	5.34	15.57	13.84	11.61	15.12	13.39	11.25
7	73.23	65.16	60.30	65.27	67.89	67.81	2.93	4.16	5.39	3.02	4.24	5.45	10.43	9.80	7.57	10.12	10.52	6.50
8	72.23	67.15	54.31	71.53	69.82	54.44	3.02	4.55	6.07	3.10	4.57	6.16	12.63	10.15	9.59	12.47	9.82	9.22
9	83.03	75.15	68.29	82.47	75.69	65.64	3.82	5.49	7.16	3.91	5.51	7.2	15.07	12.83	11.23	17.80	12.83	13.81
10	87.10	76.56	65.85	84.61	73.27	67.15	6.11	7.78	9.45	6.09	7.80	9.54	13.60	11.81	10.58	13.83	12.20	9.98
11	86.97	71.93	61.72	87.30	64.62	66.50	4.47	6.12	7.81	4.56	6.16	7.90	13.51	11.62	11.06	13.89	12.01	10.03
12	81.87	70.42	58.44	76.75	74.25	61.62	4.97	6.63	8.31	5.05	6.66	8.40	11.12	9.55	9.32	11.27	10.26	7.55
Average	78.56	70.65	61.63	75.93	70.24	61.63	3.72	5.12	6.51	3.82	5.17	6.57	13.80	12.13	10.96	14.21	11.43	10.51
Grand Mean	69.77						5.15						12.18					
CV%	3.55						5.11						8.21					

Continue Table 3:

Genotypes	W100S						TSY					
	E1	E2	E3	E4	E5	E6	E1	E2	E3	E4	E5	E6
1	17.56	17.07	14.89	19.10	17.02	17.69	52.57	38.70	29.93	51.68	38.25	29.50
2	16.12	14.97	14.57	15.93	14.82	14.70	36.48	27.04	16.00	35.59	26.59	15.57
3	21.37	21.17	18.34	22.90	19.81	20.35	45.48	33.82	26.49	44.59	33.37	26.06
4	14.71	13.17	11.92	14.62	10.86	13.46	34.60	27.10	16.31	33.71	26.64	15.88
5	11.60	10.80	10.69	12.57	9.93	9.71	13.02	10.27	9.12	12.13	9.81	8.69
6	15.47	13.87	12.62	15.25	11.56	14.06	22.59	14.89	11.86	23.48	14.44	11.43
7	12.48	11.33	10.75	12.17	11.02	11.13	31.31	28.77	24.26	32.20	29.64	23.83
8	15.77	14.53	14.26	16.97	15.09	15.98	38.49	32.46	27.78	39.38	33.33	28.20
9	17.90	16.46	16.02	19.00	16.10	16.83	46.88	34.60	29.18	47.78	35.47	29.60
10	15.04	14.42	14.00	15.35	14.02	14.12	31.63	28.77	24.26	32.52	29.64	24.68
11	15.33	14.17	13.75	15.87	13.77	14.65	33.85	26.82	22.62	34.74	27.69	23.04
12	12.24	11.72	11.30	12.67	10.98	11.61	16.54	14.37	9.91	17.43	15.24	10.33
Average	15.47	14.47	13.59	16.03	13.75	14.52	33.62	26.47	20.64	33.77	26.68	20.57
Grand Mean	14.64						29.96					
CV%	5.97						3.72					

Table 4 Means of CHC, PROC, TSY and W100S of cowpea genotypes under non stress and stress, over two years.

Genotypes	CHC		PROC		TSY		W100S	
	Non-Stress	Stress	Non-Stress	Stress	Non-Stress	Stress	Non-Stress	Stress
1	75.27	55.12	4.10	6.46	52.13	29.72	18.33	16.29
2	82.91	64.17	3.29	5.69	36.04	15.79	16.03	14.64
3	72.73	53.45	3.39	5.79	45.04	26.28	22.14	19.35
4	73.35	57.63	3.13	5.52	34.16	16.10	14.67	12.69
5	72.54	67.17	2.88	5.29	12.58	8.91	12.09	10.20
6	73.93	66.01	2.92	5.33	23.04	11.65	15.36	13.34
7	69.25	64.06	2.98	5.42	31.76	24.05	12.33	10.94
8	71.88	54.38	3.06	6.12	38.94	27.99	16.37	15.12
9	82.75	66.97	3.87	7.18	47.33	29.39	18.45	16.43
10	85.86	66.50	6.10	9.50	32.08	24.47	15.20	14.06
11	87.14	64.11	4.52	7.86	34.30	22.83	15.60	14.20
12	79.31	60.03	5.01	8.36	16.99	10.12	12.46	11.46
Average	77.24	61.63	3.77	6.54	33.69	20.61	15.75	14.06

Table 5 Estimates of stress tolerance components from potential yield and stress yield data for cowpea genotypes.

Genotypes	TSY						W100S					
	Yp	Ys	SSI	STI	TOL	GMP	Yp	Ys	SSI	STI	TOL	GMP
1	52.13	29.72	1.11	1.36	22.41	39.36	18.33	16.29	1.04	1.20	2.04	17.28
2	36.04	15.79	1.45	0.50	20.25	23.86	16.03	14.64	0.81	0.95	1.39	15.32
3	45.04	26.28	1.07	1.04	18.76	34.40	22.14	19.35	1.17	1.73	2.79	20.70
4	34.16	16.10	1.36	0.48	18.06	23.45	14.67	12.69	1.25	0.75	1.98	13.64
5	12.58	8.91	0.75	0.10	3.67	10.59	12.09	10.20	1.45	0.50	1.89	11.10
6	23.04	11.65	0.63	0.24	11.39	16.38	15.36	13.34	1.05	0.83	2.02	14.31
7	31.76	24.05	0.72	0.67	7.71	27.64	12.33	10.94	0.71	0.54	1.39	11.61
8	38.94	27.99	0.72	1.34	10.95	33.01	16.37	15.12	0.71	1.08	1.25	15.73
9	47.33	29.39	0.98	1.22	17.94	37.30	18.45	16.43	1.02	1.22	2.02	17.41
10	32.08	24.47	0.61	0.69	7.61	28.02	15.20	14.06	0.70	0.86	1.14	14.62
11	34.30	22.83	0.86	0.69	11.47	27.98	15.60	14.20	0.84	0.89	1.40	14.88
12	16.99	10.12	1.04	0.15	6.87	13.11	12.46	11.46	0.75	0.58	1.00	11.95
Average	33.69	20.61					15.75	14.06				

YP, mean yield in a non-stress environment; **YS**, mean yield in the stress environment; **SSI**, Stress susceptibility index; **STI** Stress tolerance index; **TOL,** Tolerance index; **GMP,** Geometric mean productivity

Table 6: The joint regression analysis of variance for the studied traits.

Source of Variance	d.f	Mean Squares							
		CH	FD	NB	SY	PH	PD	W100S	PR
Environments (E)	5	1789.411**	129.425**	16.975**	1236.935**	4275.773**	83.694**	32.795**	55.621**
Error a	12	2.119	1.694	0.132	0.295	7.378	2.859	2.400	0.003
Genotypes (G)	11	345.744**	1243.672**	5.498**	1539.023**	21718.737**	72.931**	139.216**	25.159**
G × E	55	42.196**	8.214**	0.404**	25.630**	233.463**	2.639**	1.038**	0.130**
Pooled error	132	6.142	4.471	0.125	1.004	3.289	1.000	0.718	0.069

Table 7 Stability parameters of cowpea genotypes for the studied traits.

Genotypes	PH				NB				FD			
	Mean	b ± SE	Bi	S^2d	Mean	b ± SE	Bi	S^2d	Mean	b ± SE	Bi	S^2d
1	51.92	0.803±0.085	-0.197	13.175**	3.117	1.219±	0.219	0.297	46.110	1.001±0.148	0.001	1.434
2	22.24	0.460**±0.103	-0.540	19.107**	3.833	0.893±	-0.107	0.029	71.820	0.806±0.377	-0.194	7.918
3	79.36	1.160±0.280	0.160	140.170**	2.702	0.819±	-0.181	0.112	57.443	0.332±0.296	-0.668	4.978
4	137.48	2.652*±0.361	1.652	232.013**	3.567	0.815±	-0.185	1.057**	63.178	0.701±0.510	-0.299	14.259*
5	51.94	0.773±0.119	-0.227	25.548**	3.537	0.715±	-0.285	0.021	65.720	1.316±0.427	0.316	10.070
6	51.16	0.586±0.507	-0.414	457.858**	4.878	1.879*±	0.879	0.586**	49.270	0.864±0.186	-0.136	2.114
7	32.14	0.620*±0.129	-0.380	29.707**	4.013	0.760±	-0.240	0.330**	53.372	1.724±0.660	0.724	23.723*
8	33.77	0.569**±0.057	-0.431	6.004	3.545	0.967±	-0.033	0.445**	59.388	1.298±0.265	0.298	4.034
9	108.60	1.915*±0.206	0.915	76.009**	3.057	1.020±	0.020	0.219**	74.053	1.006±0.324	0.006	5.905
10	44.25	0.806±0.123	-0.194	27.336**	3.248	1.343±	0.343	0.067	57.912	0.624±0.416	-0.376	9.563
11	28.70	0.547**±0.067	-0.453	8.267*	3.798	0.813±	-0.187	0.075	63.963	1.172±0.291	0.172	4.831
12	74.42	1.111±0.195	0.111	67.987*	3.548	0.758±	-0.242	0.093	61.518	1.157±0.255	0.157	3.764

b, Regression coefficient; **SE,** standard error**; Bi,** deviation from regression**; S^2d,** sums of squares due to deviation from regression

Continue Table 7

Genotypes	CHC				PROC				PL			
	Mean	b ± SE	Bi	S^2d	Mean	b ± SE	Bi	S^2d	Mean	b ± SE	Bi	S^2d
1	65.530	1.264±0.160	0.264	19.351*	5.277	0.851±0.104	-0.149	0.002	12.580	0.934±0.244	-0.066	2.317
2	74.848	1.238±0.177	0.238	23.547**	4.490	0.866±0.104	-0.134	0.002	10.987	0.819±0.225	-0.181	2.018
3	63.463	1.227*±0.061	0.227	3.030	4.588	0.867±0.104	-0.133	0.002**	16.647	1.255±0.355	0.255	4.625**
4	65.837	0.991±0.095	-0.009	7.036	4.318	0.864±0.103	-0.136	0.003	11.622	1.179±0.168	0.179	1.228
5	70.107	0.347**±0.010	-0.653	0.332	4.085	0.871±0.104	-0.129	0.001**	13.197	1.036±0.449	0.036	7.253**
6	71.418	0.555±0.237	-0.445	42.015**	4.127	0.869±0.104	-0.131	0.001	13.463	1.102±0.164	0.102	1.184
7	66.610	0.365±0.240	-0.635	43.076**	4.198	0.882±0.104	-0.118	0.001**	9.157	0.806±0.375	-0.194	5.142**
8	64.913	1.130±0.176	0.130	23.425**	4.578	1.101±0.104	0.101	0.001	10.647	0.969±0.051	-0.031	0.342
9	75.045	0.997±0.078	-0.003	4.783	5.515	1.195±0.104	0.195	0.001**	13.928	1.212±0.431	0.212	6.715**
10	75.757	1.225±0.115	0.225	10.038	7.795	1.223±0.102	0.223	0.009	12.000	0.973±0.130	-0.027	0.834
11	73.173	1.411±0.383	0.411	109.371**	6.170	1.204±0.104	0.204	0.002	12.020	0.926±0.102	-0.074	0.612
12	70.558	1.249±0.136	0.249	14.133	6.670	1.206±0.104	0.206	0.002	9.845	0.789±0.203	-0.211	1.685

Continue Table 7

Genotypes	W100S				TSY			
	Mean	b ± SE	Bi	S^2d	Mean	b ± SE	Bi	S^2d
1	17.222	1.205*±0.364	0.205	2.061	40.105	1.718**±0.071	0.718**	2.882*
2	15.185	0.630±0.066	-0.370	0.309	26.212	1.538**±0.085	0.538**	3.960**
3	20.657	1.502±0.273	0.502	1.272	34.968	1.438**±0.062	0.438**	2.219
4	13.123	1.454±0.284	0.454	1.354	25.707	1.367*±0.116	0.367**	7.147**
5	10.883	0.909±0.295	-0.091	1.439	10.507	0.282**±0.032	-0.718**	0.778
6	13.805	1.446±0.288	0.446	1.380	16.448	0.880±0.097	-0.120 NS	5.120**
7	11.480	0.664**±0.034	-0.336	0.266	28.335	0.583**±0.076	-0.417**	3.209*
8	15.433	0.887±0.253	-0.113	1.125	33.273	0.837**±0.022	-0.163**	0.496
9	17.052	1.200**±0.025	0.200	0.241	37.252	1.383*±0.113	0.383**	6.807**
10	14.492	0.579*±0.109	-0.421	0.087	28.583	0.576**±0.061	-0.424**	2.139
11	14.590	0.893±0.110	-0.107	0.083	28.127	0.880*±0.041	-0.120**	1.121
12	11.753	0.629*±0.113	-0.371	0.075	13.970	0.518**±0.072	-0.482**	2.959*

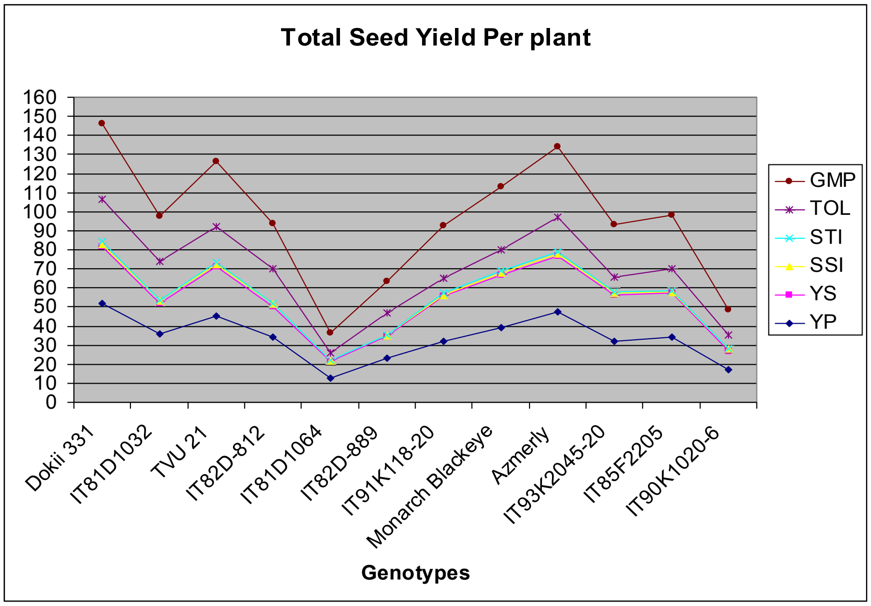

Fig. 1 Relation among total seed yield and GMP, TOL, STI, SSI, Ys and Yp

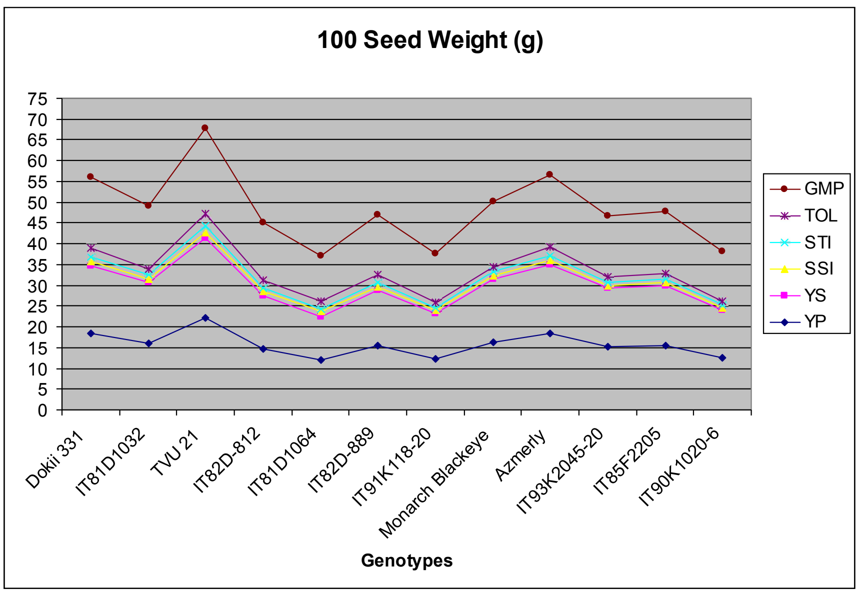

Fig. 2 Relations among weight of 100 and GMP, TOL, STI, SSI, Ys and Yp

Conclusion

From the data was present in this investigation, it can assume that genotypes IT93K2045-20, IT91K118-20, IT81D1064, and IT82D889 having drought tolerance and could b through the breeding program in improving cowpea genotypes under drought stress conditions.

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