



Drought tolerance in some populations of grass pea (*Lathyrus sativus* L.)

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ABSTRACT

In Algeria, the genus *Lathyrus* is cultivated mainly for grain production (food) and also used as fodder (animal feed). *Lathyrus sativus* L. or grass pea has a good resistance to drought, salinity and flooding. However, its place is still very limited compared to that of other pulse crops. The objective of this study was the evaluation of 05 Algerian populations and 2 varieties of *Lathyrus sativus* under drought stress applied during the flowering stage. ANOVA analysis showed that water stress at flowering stage had a significant genotype effect for most traits and significant genotype x stress interaction for flowering date, number of pods, pods weight, number of seeds per pod and seed yield per plant. 21 Lat, 4Lat4-2 and 1Lat-1 genotypes having high performance for pod length, weight pod per plant, seed yield per plant, biological yield and 1000-seed weight are more tolerant to drought.

Key words: Algerian populations, Drought stress, Genotype x drought interaction, *Lathyrus sativus*.

INTRODUCTION

In Algeria, the genus *Lathyrus* is cultivated mainly for grain production (food) and also used as fodder (animal feed) by marginal farmers. *Lathyrus sativus* L. or grass pea has a good resistance to drought and has been grown successfully in areas with an average annual precipitation of 380 mm to 650 mm (Campbell *et al.*, 1994; Hanbury *et al.*, 2000). However, its place is still very limited compared to that of other pulse crops. Water deficit is one of the most important factors that not only affect plant growth and development but also limit productivity (Boyer, 1982; Choudhary and Suri, 2014). Under this level of extreme drought, grass pea is the only productive crop and becomes the only food for the poor in some rural or marginal areas (VazPatto *et al.*, 2006). Accordingly, grass pea is considered one of the most promising sources of starch and protein for the vast and expanding populations of drought-prone areas of Asia and Africa (Jiao *et al.*, 2011; Korus *et al.*, 2008; VazPatto *et al.*, 2006).

Grass pea not only has potential as an agriculturally important crop for animal feed and human food, it also can be useful for studies of plant drought resistance (Choudhary *et al.*, 2016). The occurrence time is more important than the water stress intensity (Korte *et al.* 1983). Water stress occurring at any time during reproductive growth can result a strong change in seed yield. The most critical time to experience water deficit on many seed crops is throughout stem elongation and flowering (Kakaei *et al.*, 2010,

Garavandi *et al.*, 2011, Ahmadi *et al.*, 2012, Zebarjadi *et al.*, 2012). Compared to other legumes, grass pea has developed some morphological drought tolerance traits, including narrow leaves, stems with winged margins, and a deep and extensive root system. Basic research on the mechanisms of drought resistance by grass pea is essential to understand how this plant combats water deficit stress. As water resources become more limiting, the development of drought-tolerant crops will become increasingly important (Choudhary and Suri, 2014a, 2014b). The objective of this experiment was to determine the influences of water deficit stress applied during the flowering stage of 05 Algerian populations and 2 varieties of grass pea (*Lathyrus sativus*).

MATERIALS AND METHODS

Five Algerian populations (4Lat 4-1, 4Lat 4-2, 2lat2-1, 3lot31 and 1Lat1), and 2 varieties coming from USA, Washington (21Lat) and from Pakistan (11Lat) of *Lathyrus sativus* were evaluated under two conditions (watered and drought stress). The experiments were carried out at National Agronomic School, El Harrach, Algiers under greenhouse. Grass pea genotypes were sown in pots (14 liter) containing a mixture of 25% peat, 25% ground and 25% sand. The experiment design was split-plot with six replications. When plants reached flowering, drought was imposed to stress plots by withholding water, while non stressed plots continued receiving irrigation. Stress was relieved when 80 % of the soil available water had been exhausted. Field capacity was

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determined by gravimetric method after 72 h of draining. Pots of both treatments were weighted daily.

Plant height (PH), number of primary branches per plant (NPB), seed number per pod (SP), pods number per plant (PNP), number of seeds per plant (SNP), thousand seed weight (WS), weight pod (WP), duration of flowering (DF), pod length (POL), pod larger (PLA), peduncle length (PEL), date of maturity (DM), biological yield (BY) and seed yield (SY) were determined. Thousand seeds weight and seed yield was measured by digital scale after placing it in oven. Seed number per pod and pods number per plant were done by hand. Kjeldahl method was used to measure protein content (PROT).

$$\% \text{ crude protein} = \text{total nitrogen} \times 6.25$$

The analysis of variance (ANOVA), Correlations, Principal Component Analysis, cluster analysis was obtained by STATISTICA (Data analysis Software System, version 6, Stat Soft Inc.).

RESULTS AND DISCUSSION

Analysis of variance was done in order to study on effects of genotype and drought stress on grass pea traits. Results showed that there were significant difference among the genotypes for flowering date, maturity date, pods number per plant, thousand seeds weight, seeds number per plant and seed yield per plant indicating the presence of adequate variability among the genotypes (Table 1 and 2). The genotype \times stress interaction effect was significant for pods number per plant, weight pods, seeds number per pods, thousand seed weight, seed yield per plant and pod larger indicating that genotypes responded differently to water treatments (Table 1, 2). Gallais (1990) indicated that the presence of genotype \times environment interaction means that expression of the genes is not the same under diverse environmental conditions. Mean comparison using Newman and Keuls Test (Table 1) showed that 21Lat indicated the highest seed yield per plant in watered (21.05 g) and drought (17.13g) conditions. Seed yield has been decreased compared to watered conditions (34.11%).

The reduction in seed yield ranged from 19 to 39% compared with well-watered control, when drought stress was imposed at reproductive stage (Gunasekara *et al.*, 2006). Mafakheri *et al.* (2010) reported that the yield of varieties of pea was affected by drought stress, plants stressed at the vegetative stage, but not stressed subsequently, gave a significantly higher yield than plants stressed during anthesis or during the vegetative stage and anthesis. Keati and Cooper (1998) indicated in their study on effect of irrigation treatments on canola yield that all seed yield components decreased seed yield under drought condition.

Mean comparison showed that 11Lat give the highest number of pods per plant. Results of table 1 showed

that the average of pods per plant of grass pea genotypes under stress conditions has been decreased compared to watered conditions (39.96%). Mean comparison showed that 11Lat had the highest number of pods per plant in watered (77.5) and drought (38.3) conditions. The decrease in yield of seed legumes grown under drought conditions is largely due to the reduction in the number of pods per plant (Lopez *et al.*, 1996, Pilbeam *et al.*, 1992). Mirzaei *et al.* (2014) reported that whatever drought stress is closer to the pod formation stage, its effect will be higher on the number of pods and results showed that part of the yield loss in stress conditions is related to the reduction of number of seeds per pods and number pods. According to Mouhouche *et al.* (1998), number of pods per plant has more sensitive effects on drought stress. Results of Table 1 showed that the mean seeds number per pods of grass pea genotypes under stress conditions has been decreased compared to watered conditions (20.51%). Mean comparison showed that 11Lat genotype have the highest average seeds number per pods in watered (4.22) and drought (3.23) conditions respectively. The results showed that in all varieties, 1000-seeds weight was reduced under stress conditions than under watered condition. Usually, when water deficit stress is applied after the flowering stage, it causes the reduction of pod number per plant by shortening the flowering period, the reproductive growth duration, and finally their fertility of some flowers and their abscission (Nasri *et al.*, 2008). The mean of thousand seeds weight of grass pea genotypes under stress conditions (Table 1) has been decreased compared to normal conditions (3.1%). Pandey *et al.* (2001) showed that during water deficit stress at flowering stage, the seed yield decreases due to reducing seeds weights. Deloche (1980) showed that drought stress at seed filling stage caused to producing faded seeds.

The production of biological yield of grass pea genotypes under stress conditions (Table 1) has been decreased compared to normal conditions (25.73%). Mean comparison showed that 11Lat and 21 Lat genotypes had the highest biological yield per plant in watered (60.83g) and drought (52,07g and 44.35g) conditions respectively. Analysis of variance showed that there was a significant variation among the genotypes for days to flowering trait (Table 2). Mean comparison in non-stress conditions showed that 2Lat21 genotype with 94.2 days after sowing and genotype 11Lat with 78.8 days after sowing have known as late and early- grass pea genotypes respectively. Also mean comparison in drought stress conditions showed that 2Lat2-1 and 1Lat1 genotypes with 84.5 days after sowing and genotype 1Lat-1 with 71.8 days after sowing have known as late and early-grass pea genotypes respectively. Results of Table 2 showed that the average days to seed maturity of grass pea genotypes under stress conditions has been decreased compared to normal conditions (2.07%). Results

Table 1: Means of studied traits in watered and drought stress condition and the loss percent of traits in Grass pea.

Genotypes	Pods number		Weight pods(g)		Seeds number		Seeds number		Thousand seeds		Seed yield		Biological		Crude	
	per plant	per pod	W	S	per plant	per pod	W	S	weight (g)	W	S	per plant(g)	W	S	yield(g)	protein (%)
4Lat4-1	42.17bc	29.17bcd	22.12abc	17.48c	3.23b	2.35	88.17a	54.5a	232.61ab	199bc	16.87abc	12.67a	53.63	35.23	17.75	18.83
1Lat4-2	43.17bc	29bcd	25.65ab	20.07abc	2.72bcd	1.92d	82.67a	57a	260.81ab	241.1ab	19.9bc	14.82abc	55	40.12	16.97	18.69
2Lat2-1	40.5bcd	28cd	23.82abc	17.03c	2.78bc	2.3cd	68.0a	56.17a	226.47ab	295.46a	19.07abc	12.95a	57.85	42.05	16.89	21.23
3Lat3-1	36bcd	23.67d	22.63abc	16.95c	2.88bc	2.38cd	83.0a	53.0a	248.60ab	201.25bc	16.17abc	13.31ab	57.9	42.98	18.06	20.69
1Lat-1	41.67bc	25.5cd	25.87ab	18.18bc	2.58bcd	2.32cd	78.17a	53.17a	267.70ab	261.14ab	20.07bc	14.62abc	58.3	43.50	15.04	17.67
11Lat	77.5a	38.3bcd	19.95abc	17.22c	4.22a	3.23b	183.16d	120.33b	114.12d	89.26d	16.07abc	13.48ab	60.83	52.07	17.36	19.45
21Lat	67.83a	46.17b	26.45a	22.87abc	3.42b	2.85bc	152.17c	135.17bc	128.07d	153.17cd	21.05d	17.13abc	60.83	44.35	18.37	19.06
Means	49.83	31.41	23.78	18.54	3.12	2.48	102.62	75.62	212.49	205.9	21.46	14.14	57.76	42.9	17.21	19.37
Cv%	23.8	***	19.4	NS	15.52	NS	24.1	***	35.51	***	20.7	*	28.74	NS	13.45	NS
Genotype effect	***	***	NS	NS	NS	NS	***	***	***	***	***	*	NS	NS	NS	NS
Stress effect	***	***	**	***	***	***	***	***	NS	NS	**	**	***	***	***	*
Genotype x stress	**	**	**	**	***	***	NS	NS	*	*	***	***	NS	NS	NS	NS
The loss percent	36.96		22.035		20.51		26.31		3.10		34.11		25.73			8.68

NB. *, ** and *** = significant at p<0.05, p<0.01 and p<0.001 respectively.

Table 2: Means of studied traits in watered and drought stress condition and the loss percent of traits in grass pea.

Genotype	Flowing date		Maturity date		Plant height (cm)		Pod length (cm)		Pod larger (cm)		Number of primary branches		Peduncule length(cm)	
	W	S	W	S	W	S	W	S	W	S	W	S	W	S
4Lat4-1	82ab	75.33ab	108.33a	103.17a	97.333a	75.33a	3.78ab	3.43ab	1.55a	1.36bc	8.0a	7.33a	4.72a	3.67ab
4Lat4-2	89.33ab	79.67ab	112.33a	106.33a	96.583a	86.25a	3.42ab	3.45ab	1.4ab	1.35bc	7.67a	7.33a	4.13ab	2.75b
2Lat2-1	94.17c	84.5ab	111.83a	111.17a	94.167a	86.25a	3.83a	3.4ab	1.45ab	1.28bcde	7.83a	6.33a	4.08ab	3.5ab
3Lat3-1	86.17ab	75.67ab	112.33a	109.83a	90.67a	89.17a	3.78ab	3.38ab	1.32bcd	1.23cde	7.17a	6.5a	4.32a	3.2ab
1Lat-1	85.67ab	71.83a	113a	111.33a	87.167a	74.67a	3.82ab	3.45ab	1.4abc	1.35bc	6.67a	6.5a	3.72ab	2.72b
11Lat	78.83ab	76.5ab	85b	87.83b	90.67a	78.42a	3.77ab	3.13b	1.15def	1.1ef	7.0a	6.0a	4.72a	3.78ab
21Lat	79.00ab	74.00a	105.5a	102.5a	91.67a	84.67a	3.78ab	3.53ab	1.1ef	1.02f	7.5a	6.5a	3.67ab	3.88ab
Means	85.02	76.79	106.9	104.59	92.63	81.47	3.8	3.4	1.34	1.24	7.4	6.64	4.19	3.36
Cv%	13.59		10.2		19.93		10.86		14		24.41		24.75	
Genotype effect	**	***	***	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Stress effect	***	***	NS	NS	**	**	**	**	***	***	*	*	***	***
Genotype x stress	NS	NS	NS	NS	NS	NS	NS	NS	***	***	NS	NS	NS	NS
The losspercent	9.68		2.07		12.05		10.53		7.46		10.27		19.51	

NB. *, ** and *** = significant at p<0.05, p<0.01 and p<0.001 respectively, NS = non significant.

of Table 2 showed that the average height of grass pea genotypes under stress conditions has been decreased compared to normal conditions (12.05%). The results indicate that stress limits the plant vegetative and reproductive growth.

The results showed that in all varieties, pod length was reduced under stress conditions than under normal irrigation. Results of Table 2 showed that the average pod length of grass pea genotypes under stress conditions has been decreased compared to normal conditions (10.53%). Mean comparison showed that 4Lat4-1 had the highest pod larger in normal (1.55 cm) and drought (1.36cm) conditions. The results showed that in all varieties of pod larger was reduced under stress conditions than under normal irrigation (7.46%). Results of Table 2 showed that the average number of branches per plant of grass pea genotypes under stress conditions has been decreased compared to normal conditions (10.27%). Due to reduced branch number followed by stress, causing reduced production and stimulating branch primordia and reducing in transport of assimilates (Kahrizi and Allahvarand, 2012). Results of Table 2 showed that the average peduncle length of grass pea genotypes under stress conditions has been decreased compared to normal conditions (19.51%).

The analysis of variance of the percentage of the crude protein did not show any significant difference among genotypes (Table 2). The mean crude protein of grass pea genotypes under stress conditions has been increased compared to normal conditions (8.68%). These findings are in accordance with those obtained by Henry and MacDonald (1978), Khalid (2006) and Osuawagwu and Edeoga (2013). Our crude protein values were lower than those reported by Granati *et al.* (2001), Milczak *et al.* (2001) and Karadag and Yavuz (2010). Karadag and Yavuz (2010) explained that the different cultivars have different growth and crude protein productions and soil nitrogen level also affected the plant crude protein values. Osuawagwu and Edeoga (2013) reported that the increase in the percentage ash, crude protein and crude fat content of the leaves of *O. gratissimum* and *G. latifolium* might be due to their increased production by plant in response to water stress.

Principal component analysis: Principal component analysis for two treatments [watered (W) and drought stress(S)] was performed based on fifteen traits and the two first components together accounted for 72.65% of the variability (Table 3). First component accounted for 43.09% and the second one for 29.29%. Correlation of the analyzed traits with the first two principle components was given in Table 3.

The first component was associated negatively with: PH, pod length (POL), peduncle length (PEL), pod number per plant (PNP), weight pod (WP), seeds number per pod (SP),

Table 3: Principal component analysis (PCA) of genotypes based on traits

Parameter	PC1	PC2
Eigen values	6,462	4,393
% of variance	43,085	29,287
Cumulative %	43.085	72.3736
Characters	Eigenvector	
FD	-0,506405	-0,692532
MD	0,221417	-0,872546
PH	-0,645810	-0,325807
POL	-0,732618	-0,359052
PLA	0,070025	-0,814327
NPB	-0,511657	-0,557602
PEL	-0,767564	0,056854
PNP	-0,853785	0,420864
WP	-0,754012	-0,402716
SP	-0,768117	0,506178
SNP	-0,699011	0,683093

seed number per plant (SNP), seed yield per plant (YSD), biological yield per plant (BY) and crude protein (PROT). The second component was associated positively with flowering date (FD), maturity date (MD), larger pod (PLA), number of primary branches (NPB) and negatively with thousand seeds weight (SW). In the case of the projection of individuals in the plan 1-2, a clear separation between the local population and foreign varieties was noted (Fig. 2) due to their geographical origin. Also, within local populations is an opposition between local genotypes (4lot4-1W, 4lot4-2W, 2lot2-1W, 3lot3-1W and 1lot1W) under watered (W) treatment with the higher values of seed yield per plant, pod weight, pod length, plant height, primary branches number and flowering date. The same genotypes but under drought (S) treatment (4Lat4-1S, 4Lat 4-2S, 2Lat2-1S, 3Lat3-1S and 1Lat1S) have high value of larger pod, maturity date and thousand seeds weight. However, for foreign varieties, similar behavior for 11sats genotypes 21LatS 21LatS and 11LatS with high pod number per plant and seeds number per plant and (Fig. 2).

Correlations: The Pearson correlation has been evaluated for both treatments (watered and drought stress). Traits simple correlation (Table 4) showed that seed yield was significantly and positively correlated with pod number per plant ($r = 0.566^*$), plant height ($r = 0.608^*$), weight pod ($r = 0.977^{***}$) and pod length ($r = 0.663^{**}$). These results were consistent with those obtained by Zirgoli and kahrizi (2015) who reported that as there is significant relationship between seed yield and pods per plant and pod length. Then for plant breeding and selection, it is possible that pods per plant and pod length could be selected. Sadaqat *et al.* (2003) found that Seed yield had significant positive correlations with plant height, pods per plant and branches per plant under drought conditions. Positive correlations among the number of pods per plant and the traits: seeds number per plant ($r = 0,870^{***}$), seeds number per pod ($r = 0,923^{***}$) and

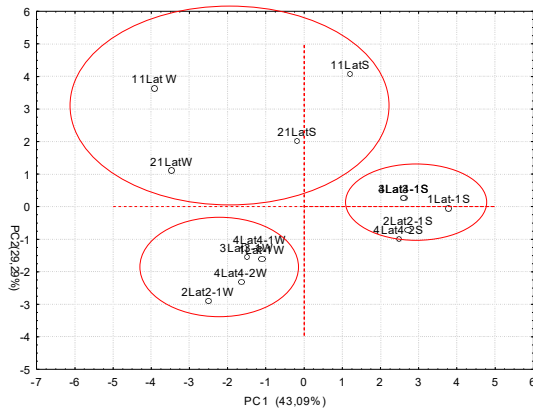


Fig 1: Distribution of traits based on the first two components

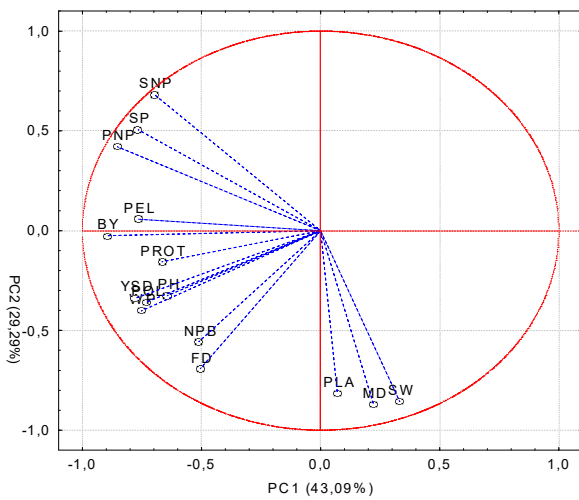


Fig 2: Distribution of genotypes based on the first two components

biological yield per plant ($r = 0,719^{**}$), which corresponds with the results of Cambell (1997) and Benková and Žáková (2001), according to his statement that high seeds weight have set more pods per plant. The correlations between crude protein and flowering date ($r = 0.548^*$); plant height ($r = 0.592^*$) and peduncle length ($r = 0.654^*$) were significant. Other positive and significant correlations were recorded for biological yield with plant height ($r = 0.581^*$), pod length ($r = 0.656^*$) and peduncle length ($r = 0.648^*$). There was a high significant positive correlation between the number of days to flowering and the plant height ($r = 0,683^{**}$). Days to maturity had positive and significant correlation with pod larger ($r = 0.567^*$) and negative and significant correlations with pod number per plant ($r = -0.551^*$), ($r = -0.638^*$), seeds number per plant ($r = -0,713^{**}$) and thousand seeds weight ($r = 0,814^{***}$). Vidyadhar et al. (2007) obtained significant correlations with days to flowering with days to maturity, plant height, leaf length, leaf width, stem diameter and fodder suggesting that these characters may be of merit while making selections for high fodder yield hybrids in pearl millet.

Cluster analysis: The data were used for hierarchical cluster analysis using ward method and interval squared Euclidean distance. Cluster analysis results showed that grass pea genotypes were divided to 3 groups (I, II, III) under both conditions (Fig. 3). The results found by clusters analysis (Figure 3) are identical to those obtained by the ACP.

CONCLUSION

The results indicated the impact of drought on different genotypes of grass pea in almost all the traits. The genotype \times stress interaction was significant for some traits

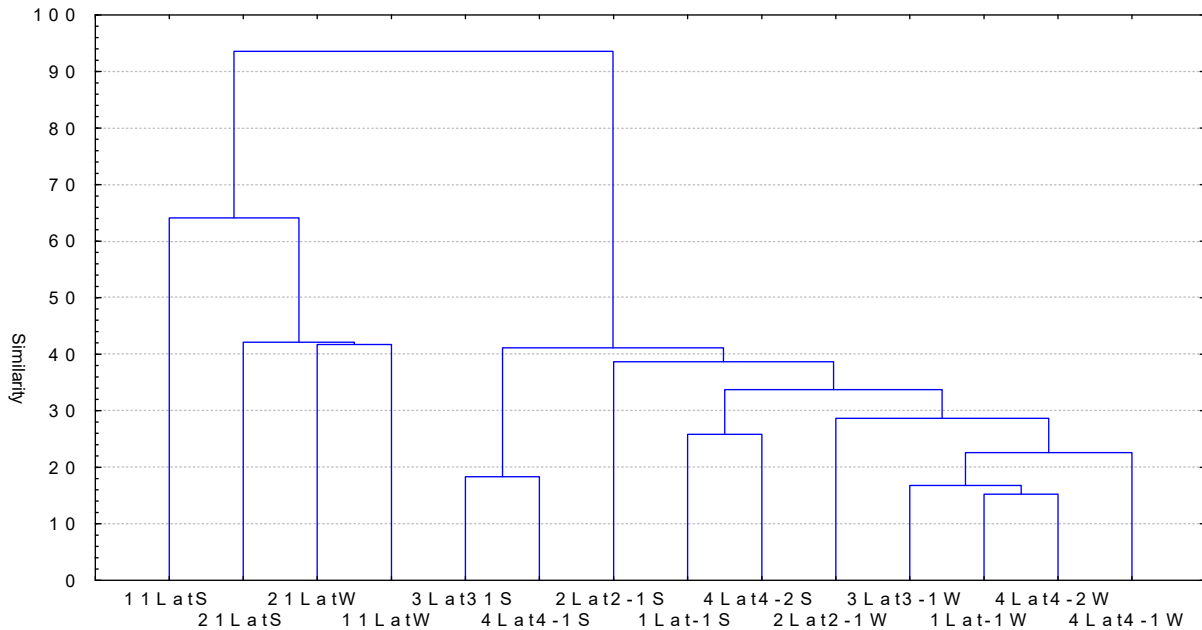


Fig 3: Dendrogram of 07 grass pea genotypes based on 15 characters

Table 4: Correlation coefficient among studied traits in Grass pea.

	Flowering date	Maturity date	Plant height	Pod length	Pod larger	Number of primary branches	Peduncle length	Pod number per plant	Weight pod	Seeds number per pod	Seeds number per plant	Thousand seeds weight	Seed yield per plant	Biological yield
Maturity date	0,388ns													
Plant height	0,683**	0,200ns												
Pod length	0,465ns	0,168ns	0,412ns											
Pod larger	0,528ns	0,567*	-0,039ns	0,296ns										
Number of primary branches	0,518ns	0,342ns	0,348ns	0,581*	0,589*									
Peduncle length	0,424ns	-0,287ns	0,309ns	0,514ns	0,089ns	0,419ns								
Pod number per plant	0,082ns	-0,551*	0,410ns	0,524ns	-0,394ns	0,259ns	0,604*							
Weight pod	0,547*	0,250ns	0,595*	0,673**	0,141ns	0,550*	0,377ns	0,501ns						
Seeds number per pod	0,056ns	-0,638*	0,230ns	0,403ns	-0,299ns	0,165ns	0,747**	0,870***	0,241ns					
Seeds number per plant	-0,163ns	-0,713**	0,234ns	0,279ns	-0,650*	-0,022ns	0,540*	0,923***	0,311ns	0,854***				
Thousand seeds weight	0,442ns	0,814***	0,069ns	0,119ns	0,737**	0,185ns	-0,254ns	-0,600*	0,076ns	-0,650*	-0,785***			
Seed yield per plant	0,527ns	0,189ns	0,608*	0,663**	0,109ns	0,514ns	0,355ns	0,566*	0,977***	0,320ns	0,363ns	0,012ns		
Biological yield	0,530ns	-0,185ns	0,581*	0,656*	-0,003ns	0,319ns	0,648*	0,719**	0,690**	0,749**	0,586*	-0,236ns	0,744**	
Crude protein	0,548*	-0,021ns	0,592*	0,510ns	-0,013ns	0,456ns	0,654*	0,375ns	0,411ns	0,364ns	0,284ns	-0,203ns	0,356ns	0,466ns

NS, *, ** and ***: non significant, Significant at 5%, 1% and 0,1% probability levels, respectively

indicating that the genotypes responded differently to irrigation treatments. Results show that drought stress caused low seed yield due to deficiency of irrigation at critical stage. Seed yield per plant under drought conditions can be improved by improving plant height, pod length, and weight pod per plant. Plant traits including plant height, pod length and weight pod per plant can be

used for indirect selection of high yielding grass pea genotypes under water stress. 21 Lat, 4Lat4-2 and 1Lat-1 genotypes having high performance for pod length, weight pod per plant, seed yield per plant, biological yield and 1000-seed weight are more tolerant to drought conditions. These genotypes could be used as source of germplasm for breeding of drought tolerance.

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