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Assessment Quantitative and Qualitative factors of Peanut (*Arachis hypogaea* L.) under Drought Stress and Salicylic Acid treatments

Mohammad Ali Karimian*, Mehdi Dahmardeh**, Fatemeh Bidarnamani* and Mohammad Forouzandeh*

**Agricultural Research Institute, University of Zabol, IR, IRAN.*
***Department of Agriculture, Agriculture Faculty, University of Zabol, IR, IRAN.*

(Corresponding author: Mohammad Ali Karimian)
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ABSTRACT: In order to study the effects of drought stress and salicylic acid on quantitative and qualitative characteristics of peanut crop, a research was conducted in 2013 in the Institute of Agriculture, University of Zabol as a splitted- plot experiment based on a randomized completely block design with three replications. The main plots included three irrigation regimes, 90 (control), 70% and 50% humidity of field capacity and four levels of salicylic acid, control, 1, 2 and 3 mM were considered as the sub plot factors. The studied traits were dried herb yield, pod yield, seed yield, 100- seed weight, number of pods per plant, content of kernelling, protein and oil content of the seed. The results showed that drought had a significant impact on the studied properties so that severe stress (50% of field capacity moisture) makes a 42.83% increase in grain protein content and decreases yield of dry plant, seed yield and seed oil content by 45.23, 38.65, and 23.32%, respectively. In contrast, salicylic acid increases the quantitative traits significantly, but the percentage of protein and oil was neutral. The interactional effect of drought and salicylic acid on all traits except seed oil content was significant. The results showed that using 3 mM salicylic acid in drought conditions had left significant and positive effects on quantitative and qualitative characteristics of peanuts, so it can be a good alternative in Sistan region for reducing the severe impact of water shortage.

Keywords: Peanut, drought, grain yield, content of seed protein, content of seed oil

INTRODUCTION

After soybean oil, Peanut (*Arachis hypogaea* L.) is one of the most important and economic pellets in tropical and subtropical regions mostly planted to produce 43-55% oil and protein (Holbrook and Stalker, 2003). Peanut seeds is mainly used in preparation of edible oil, conserve, margarine, soap and the like. Peanut meal is also an invaluable feed for livestock and its nutritional value is the same as soybean meal. After sunflower, It has the highest percentage of sunflower oil among seed crops (Khajehpour, 1999). Humidity stress, which is a part of general stresses, has undesirable effects on plant growth and crop production (Blum, 2005). The stress caused by anatomical, morphological, physiological and biochemical changes affect different aspects of plant growth and development and the severity of the drought damage depends on the duration of this stress and various growth stages. This stress reduces photosynthesis, Stomata conductance, biomass, growth and ultimately result in plant yield (Abdul Jaleel *et al.*, 2009). Salicylic acid is one of the important signalling molecules that cause the reaction of the plant against environmental stresses. Like a non- enzyme antioxidant, this material plays a crucial role in regulating various physiological processes such as growth, plant development, ion uptake, photosynthesis and concentration- based germination, plant, species, developmental period and environmental factors (Arfan *et al.*, 2007; Iqbal *et al.*, 2006). This substance contributes in plant defense response to abiotic stresses such as drought, heat and cold (Yuan and Lin, 2008). Acting mechanism of salicylic acid against stresses is contributed to its role in regulation of antioxidant enzymes and compounds including various species of active oxygen in plant (Shi and Zhu, 2008). Salicylic acid increases antioxidant enzymes and supports the plant against damage resulted from oxidative reactions. Moreover, using salicylic acid increases putrescine, spermidine and spermine polyamins and in this way, it helps and maintains its membrane integrity under stress conditions (Nemeth *et al.*, 2002). Application of salicylic acid in a concentration of 10-5 molar in leaves of the located plants of Indian mustard (*Brassica juncea* L.) has increased dry matter accumulation, and the results showed that stem thickness, number of leaves, shoot dry and wet weight increase in response to salicylic acid (Fariduddin *et al.*, 2003).

Using salicylic acid with seeds in tomato and bean can increase its tolerance against stresses such as heat, drought and coldness (Senaratna *et al.,* 2000). It has been reported that the use of acetyle salicylic acid with concentrations of 0.1-1 Mm as seed soaking and foliar spray on melon seedlings reduces the effects of drought on the plant (Korkmaz *et al.,* 2007). The use of salicylic acid with concentrations of 50, 100 and 150 ppm on rice seedlings under drought stress conditions, 50% of field capacity could significantly increase the performance of the plant (Farooq *et al.,* 2009). In addition, under drought stress, the use of salicylic acid in Wheat plant increased photosynthesis rate (Hamada and Al-Hakimi, 2001), protein and sugar content in shoots and roots (Mohamed and Ahmed, 2010) and leaves chlorophyll (Singh and Usha, 2003). Furthermore, salicylic acid increased the shoot growth of barley (Pancheva *et al.,* 1996), wheat (Shakirova, 2007) and soybean (Gutierrez Coronado et al., 1998) and increased the concentration of lignin in the cell walls of wheat (Al-Hakimi, 2008). Due to the fact that Sistan is located in a hot and arid region, the importance of water in agricultural production and the need to produce products with a greater economic value, the present study was done to examine the effects of different levels of Salicylic acid and drought stress on qualitative and quantitative characteristics of peanuts.

MATERIALS AND METHODS

This experiment was performed during the Agricultural years, 2012-2013, in the Agricultural Research Station of the University of Zabol, 61° 41' east longitude, 30° 54' north latitude and its altitude was 495 m above the sea level. The 40-year mean temperature was 23°C with a maximum amount of 49°C and a minimum temperature of -7°C. The analysis results of the physical and chemical soil test before planting are presented in Table 1. The experiment was performed as Split plot in a randomized completely block design with three replications. Treatments consisted of three levels of irrigation: the control or 90% of the field capacity moisture (I1), 70% of field capacity moisture (I2) and 50% field capacity moisture (I3) as the main factors and four levels of salicylic acid: S1 (Control), no salicylic acid consumption, S2 = 1, S3 = 2 and S4 = 3 mM foliar as the sub-factors. During the autumn, the selected land was plow by the moldboard. Then, two perpendicular disks were used to soften the hard agglomerates and then, the land was cleared by a trowel. The land was shaped as beds and stacks, and the basic NPK fertilizers were used based on soil analysis while striped planting with considering the distance between seeds planted deep in the ground. Irrigation was performed and after Appropriate soil moisture, planting was done manually on 30 May 2013. After excluding margin plots, sampling from the middle two rows of each plot was taken at 0.6 square meter. To calculate the yield of dried herb, pod-separated harvested plants were measured and kept for 48 hours in an oven at 74°C. After harvesting, to reduce the amount of moisture, the pods were put in fresh air for four days. Then, the pods were kept for 48 hours in the oven at 60°C to reach their constant dried weight. Finally, the pods were weighed by a scale of 0.01 accuracy and the pod yield was calculated. Seed yield was also obtained through multilicity the pods' yield by percentage of kerneling. In all treatments used for determining 100 seeds' weight, 200 grams of dried pods were selected and peeled. Then, 100 seeds were selected randomly and their weight was determined with a 0.01 g accuracy scale. Percentage of kernelling, used in a sample to determine the weight of 100 seeds, was also measured through dividing the seeds' weight by the pods' weight ×100 (Rasekh *et al.,* 2006). To determine the protein content of seed, first the grain nitrogen content was determined using the crude automatic machine and then, after multiplying this value by a factor of 6.25, the protein content in the grain was calculated (Anonymous, 2002). Seed oil was also isolated by solvent extraction with a Soxhlet apparatus (Soxhlet, 1879). Analysis of data variance was performed using SAS software data, version 9.1 and the averages were compared based on the Duncan multi- range test at 5% level. To draw the graphs and tables, Word and Excel software was used.

Table 1: Physical and chemical characters of soil (0-30cm).

Soil texture	Clay	Silt	Sand	O.M %	EC ds/m	P	K	N %	pH
	%					ppm	ppm		
Loamy	10	50	40	1.35	2.8	10.5	110	0.067	7.5

RESULTS AND DISCUSSION

A. Dried plant yield

Analysis of data variance showed that drought stress, salicylic acid and interaction of salicylic acid on drought stress were significant at 1% level (Table 2).

Comparison of the data averages showed that if drought stress of the control increases to 70 and 50%, the agricultural capacity of the dried crop yield increases by 33.7 and 45.23%, respectively (Table 3).

Table 2: Analysis of variance characteristics of peanut in effect of drought stress and Salicylic Acid.

s.o.v	df	Dried plant yield (ton.hac)	Pod yield (kg.hac)	Seed yield (kg.hac)	100- Seed weight (gr)	Number of pods per plant	Content of kernel (%)	Protein content (%)	Seed oil content (%)
Replication	2	0.300^{ns}	1437.49 ^{ns}	2665.206^{ns}	24.659^{ns}	2.363^{ns}	0.065^{ns}	22.268^{ns}	4.52^{ns}
drought	2	38.308**	470984.512**	540028.637**	241.629**	105.226**	119.6**	37.348*	37.902*
Error a	4	0.297	3921.223	7083.961	11.896	1.588	0.095	18.038	3.938
Salicylic Acid	3	4.322**	530218.947**	241428.575**	532.19**	142.325**	127.107**	9.455	4.883^{ns}
Salicylic Acid × drought	6	12.974**	958435.706**	294125.145**	229.864**	187.194**	160.194**	36.694*	11.946^{ns}
Error b	18	0.230	13680.601	3948.224	12.004	1.056	0.173	8.113	7.044
CV %	-	8.56	8.5	7.35	6.93	4.73	7.44	11.71	6.46

ns,** ,* respectively not significant and significant at the level of probability is 1% and 5%.

Table 3: Mean comparison the effect of drought stress on qualitative and quantitative yield of peanut.

Stress levels / Traits	50% of field capacity field	70% of field capacity field	90% of field capacity field
Dry plant Yield	7.601a	5.039b	4.163c
Pod yield	1604a	1312b	1058c
Seed yield	996a	825b	611c
100- Seed weight	55.38a	49.15b	43.07c
Number of pods per plant	24.83a	21.33b	18.94c
Content of kernel	9.137a	4.594b	3.068c
Protein content	17.12c	23.7b	29.95a
Seed oil content	42.49a	37.72b	32.58c

Common letters in each row indicate no significant difference at the level analysis of variance.

Due to water shortage, the cell volume, the cell division, the cell wall, the overall size of the plant, and the wet and dry weights of the plant will decrease (Earl and Davis, 2003). Drought stress is the major cause of yield loss in crops. It is reported that drought stress can reduce the dry matter of maize (Cakir, 2004). Dry weight of maize forage under drought conditions decreased by 21% compared to the control (Mehrabian Moghadam *et al.,* 2011). The results showed that drought stress could reduce 19% of the dry weight of shoots in cucumber (Bayat *et al.,* 2011). Any increase in Salicylic acid intake was associated with increased performance of dry plant (Table 4). Taking 1, 2 and 3 Mm, salicylic acid increased the dry yield of peanut by 15.61, 27.09, and 35.82%, respectively, compared to the control (Table 4). The exogenous application of some compounds including growth regulator may contribute in lowering the effects of environmental stresses to the help increase growth and yield crop plants (Ozmen *et al.*, 2003). The use of salicylic acid with 1 Mm concentration under drought conditions can increase the cucumber plant dry weight (Bayat *et al.,* 2011.) the average comparison of drought stress interaction on salicylic acid showed that the highest yield value of the dry plant (10.81 tons/ha) was related to application of 3 Mm salicylic acid under stress- free conditions (Table 5). It is reported that seed priming with salicylic acid can result in improved plant growth in normal and dry conditions. Thus, the biomass of the primed cowpea under drought stress will have less reduction (Pakmehr *et al.,* 2011).

B. Pod yield

The analysis results of the pod yield variance showed that drought stress, salicylic acid and interaction of drought stress on salicylic acid was significant at the 1% level (Table 2).

Comparison of the data averages showed that with increasing drought stress of the control to 70 and 50%, the field capacity of peanut pod yield decreased by 18.2 and 34.3%, respectively, compared to the control (Table 3). Due to the fact that at the beginning of the reproductive stage, there is a great rivalry between the tanks in formation (flowering and growing pods) for the available photosynthetic materials, it seems that water shortage in the reproductive stage may lead to factors such as severe decrease of photosynthesis, increased volume of ABA, reduced loading content of the processed materials and ultimately loss of flowers and pods (Clavel *et al.*, 2005). The result of the research on different levels of irrigation and plant density on seed and components yield of chickpea revealed that irrigation levels has reduced the number of pods per plant and the irrigation till the flowering period had the highest number of pods per plant (Rai *et al.*, 2007). drought stress decreased the number of pods per main and lateral branch of cowpea (Shekari *et al.*, 2010). Salicylic acid intake increased the pod yield (Table 4). Consumption 1, 2 and 3 Mm salicylic acid increased the pod yield by 19.37, 31.16, and 34.67%, respectively, compared to the control (Table 4). Increase cowpea pods affected by priming salicylic acid have been reported (Shekari *et al.*, 2010). Average comparison of the interaction of drought on salicylic acid showed the highest pod yield (2147 kg. ha) was contributed to using 3 Mm salicylic acid under the control irrigation condition (Table 5). Salicylic acid adjusts cellular Extension, division and death and in fact, it creates a balance between growth and aging (Popova *et al.*, 1997).

Table 4: Mean comparison the effect salicylic acid on qualitative and quantitative yield of peanut.

SA / Traits	Control (without salicylic acid)	1 mM salicylic acid.	2 mM salicylic acid.	3mM salicylic acid.
Dry plant Yield	4.465d	5.291c	6.124b	6.958a
Pod yield	1036c	1285b	1505a	1586a
Seed yield	638d	752c	863b	1096a
100- Seed weight	43.42c	48.44c	55.21b	62a
Number of pods per plant	17d	20.55c	22.77b	26.48a
Content of kernel	3.166d	4.836c	7.197b	11.2a
Protein content	23.28a	23.61a	25.11a	25.3a
Seed oil content	40.04a	41.1a	41.47a	41.8a

Common letters in each row indicate no significant difference at the level analysis of variance.

Table 5: Interaction drought stress and salicylic acid on quantitative and qualitative yield of peanut.

Traits	Dry plant Yield	Pod yield	Seed yield	100-Seed weight	Number of pods per plant	Content of kernel	Protein content	Seed oil content
Control × Without SA	4.196ef	1217f	773d	34.96e	16f	2.69fg	21.53bc	39.83a
Control × 1 mM SA	4.849e	1398def	927c	50cd	22d	3.403ef	23.83bc	41.53a
Control × 2 mM SA	5.852d	1562cd	1033bc	57.33ab	23cd	4.263cd	25.7abc	42.95a
Control × 3 mM SA	10.81a	2147a	1204a	63.3a	39a	9.27a	30.6a	44a
Average stress × Without SA	3.596f	879g	286e	34.36e	14g	2.433g	21.46bc	39.46a
Average stress × 1 mM SA	4.759e	1391def	792d	49.6cd	20e	3.403ef	21.76bc	40.65a
Average stress ×2 mM SA	5.028e	1461de	1009c	54.33bc	23cd	3.897cde	25.6abc	42.73a
Average stress ×3 mM SA	8.727b	1836b	1158a	62.33a	27b	6.617b	28.2ab	43.7a
Intense stress × Without SA	2.73g	153h	161f	33e	9h	2.323g	20.4c	39.32a
Intense stress × 1 mM SA	4.697e	1270ef	782d	47.66d	17f	2.783fg	21.66bc	40.25a
Intense stress × 2 mM SA	5.013e	1456de	1007c	52.33bcd	22d	3.65de	24.73abc	42.7a
Intense stress × 3 mM SA	6.95c	1732bc	1123ab	61a	24c	4.46c	26.43abc	43.2a

Similar letters in the each column indicate no significant difference between them

C. Seed yield

Analysis results of data variance showed that drought stress, salicylic acid and interaction of drought stress on salicylic acid was significant at the 1% level (Table 2). Comparison of the data averages showed that with increasing drought stress of the control to 50 and 70% decreased the capacity of the field grain yield to 17.16 and 38.65%, respectively (Table 3). Yield loss caused by moisture stress depends on genotype, plant developmental stage, severity and duration of water shortage (Korte *et al.*, 1993).

Under drought conditions, the peanut agronomic characteristics and grain yield of all cultivars decreased, and a significant reaction of the genotypes was observed (Vorasoot *et al.,* 2003). Effect of different levels of irrigation on 10 mungbean genotypes showed that through the loss of flowers and pods, severe and mild water stresses in all genotypes could generally decrease the yield by 45-60%, compared to the control (Pandey *et al.,* 1984). The results showed that different levels of irrigation could reduce the corn grain yield. The highest and the lowest grain yields were obtained during 4-day and 8-day irrigation periods, respectively (Ebrahami and Jafari Haghighi, 2012). Taking 1, 2 and 3 Mm salicylic acid increased the peanut yield by 15.15, 26.07, and 41.78%, respectively, compared to the control (Table 4). The study conducted during two consecutive years 2009-2010 on the effect of salicylic on Mung plant, showed that levels of salicylic acid significantly increased the grain yield compared with the control (Ali and Mahmoud, 2013). The foliar of the salicylic acid increased the grain yield (Khan *et al.,* 2010). Average comparison of the interaction of drought stress in salicylic acid showed that the highest grain yield (1204 kg.ha) was because of taking 3 mM salicylic acid and drought- free stress (Table 5). Application of salicylic acid increases polyamins putrescine, spermidine and spermine in maize plant and thus helps to maintain membrane integrity under stress conditions (Nemeth *et al.,* 2002). Salicylic acid and acetylsalicylic acid effectively support tomato and bean plants against drought stress at concentrations of 0.1 and 0.5 Mm and ultimately increases plant growth and yield in these situations (Senaratna *et al.,* 2000). Taking salicylic acid with concentrations of 50, 100 and 150 ppm on rice seedlings under drought stress conditions and 50% of field capacity increased the plant yield significantly (Farooq *et al.,* 2009).

D. 100- Seed weight

Analysis results of data variance showed that drought stress, salicylic acid and drought stress interaction on salicylic acid were significant at 1% level (Table 2). The comparison of data averages showed that with increasing drought stress of the control to 50 and 70% of the field capacity decreased the weight of 100 peanut seeds by 11.24 and 22.22%, respectively (Table 3). In conventional beans, water stress at flowering stage increases the time span required for producing the reproductive organs for those pods that are formed in lower parts of the stem, whereas the time required for the pods that are formed at the top of the stem is shorter. It might have an impact on the final weight of the seeds and the result is reduction of the 100- seed weight (Shekari, 2006). The results have shown that the weight of 100 peanut seeds has reduced due to drought stress (Doroudian, 2011). Taking 1, 2 and 3 mM salicylic acid increased 100-peanut seed weight by 10.36, 21.35, and 29.96%, respectively, compared to the control (Table 4). Seeds primed with 2700 Salicylic acid allocated the highest weight of 100 seeds per pod in side branches (Shekari *et al.,* 2010). Interactions between drought stress and salicylic acid showed that the highest 100-seed weight (63.30 gr) was due to taking 3 mM salicylic acid under the control irrigation (Table 5). Other researchers have also confirmed these results (Pakmehr *et al.,* 2011).

E. Number of pods per plant

The results of the statistical analysis of the data in Table 2 show that drought stress, salicylic acid and drought stress interaction on salicylic acid was significant at 1% level. Comparison of the data averages showed that with increasing drought stress of the control to 50 and 70% of the field capacity, the number of pods per plant reduced by 14.09 and 23.72%, respectively (Table 3). Number of pods per plant was the most vulnerable item damaged by drought stress (Pandey *et al.,* 1984). The effect of drought stress on the yield of three bean cultivars showed that stress at flowering stage reduced the number of pods per plant and seeds per pod in all three varieties (Fienebaum *et al.,* 1991). It is reported that the number of pods per plant canola reduced due to drought stress (Seyed Ahmadi *et al.,* 2011). Number of pods per plant was affected by salicylic acid treatments (Table 4). Taking 1, 2 and 3 mM salicylic acid increased the number of peanut pods per plant by 17.27, 25.34, and 35.8%, respectively, compared to the control (Table 4). Plants treated with salicylic acid, which were independent of 1-3 mM concentration of salicylic acid and of surface tension of water, normally showed a total higher moisture content, dry weight, RUBISCO carboxylase activity, super-oxide dismutase activity (SOD) and chlorophyll content than untreated wheat plants (Singh and Usha. 2003). Seeds primed with 2700 Micromolar of salicylic acid owned the major and minor number of pods per main and side branches under irrigation conditions, whereas the lowest number of pods per main branch was related to the controlled treatment under stressed condition within the podding stage (Shekari *et al.,* 2010). Average comparison of the drought stress interaction in salicylic acid showed the highest number of pods per plant (39) was related to application of 3 mM salicylic acid under non-stress conditions (Table 5). Safai (2013) stated that the highest pod in Mung plant, 5.1, was obtained under non-stress and foliar application of 1.5 mM salicylic acid and the lowest number of pods, 1.73, was obtained during a 15 day irrigation period without foliar application of salicylic acid.

F. Content of kernel

Analysis results of data variance indicated that drought stress, salicylic acid and drought stress interaction on salicylic acid was significant at the 1% level (Table 2). Comparison of the data averages showed that increased drought stress of the control to 50 and 70% of the field capacity, Content of kernel decreased by 49.72 and 66.42%, respectively (Table 3). Taking 1, 2 and 3 Mm salicylic acid increased peanut kernelling percentage by 34.53, 56, and 71.73%, respectively compared with the control (Table 4). The average comparison on the interaction between water stress in salicylic acid showed that the highest percentage of kernelling (9.27) was related to taking 3 mM salicylic acid under stress free conditions (Table 5).

G. Protein content

Analysis results of data variance showed that drought stress and the interaction of drought stress on salicylic acid was significant at the 5% level, whereas salicylic acid showed no significant effect on the trait of interest (Table 2). Comparison of the data averages showed that at 5% level, any increase in the levels of drought stress of the control to 50 and 70% could increase the field capacity of grain protein by 27.76 and 42.3%, respectively, compared with the control (Table 3). Under drought stress conditions, especially during the grain filling stage, the net photosynthesis decreased, and incomplete the potential grain weight was mainly due to starch, the protein proportion to starch in grains increased, and consequently, protein content increased. The experimental results suggest that under conditions of drought stress, protein content increased due to reduction of the proportion of starch in the grain (Jalilian *et al.*, 2005). Average comparison of drought stress interaction in salicylic acid showed that the highest protein content (30.6) was caused by taking 3 mM salicylic acid under stress free conditions (Table 5). Increased protein levels under the effect of salicylic acid treatments, especially in the spray treatment with 1.5 mM concentration of salicylic acid can be due to the stressful effect of salicylic acid increased anti- stress proteins, metabolic activities or increased levels of the stored protein. It has been reported that under drought conditions, salicylic acid could improve the bean seed protein (Sadeghipour and Aghaei, 2012).

H. Seed oil content

Analysis result of data variance indicated that drought stress was significant at 1 % level, but salicylic acid and drought stress interaction in salicylic acid had no significant effect on the trait of interest (Table 2). Comparison of the data averages showed that with increasing drought stress from the control to 50 and 70%, the field capacity in peanut oil seed content decreased by 11.22 and 23.32%, compared to the control (Table 3). The results of the drought stress effects on yield and oil content of safflower varieties under irrigation with saline water showed that the seed oil content has fallen from 42.92 to 38.91% (Kafi and Rustami, 2007). The droughts stress decreased the oil content of safflower so that the average oil content decreased from 42.92 to 38.91% (Seyed Ahmadi *et al*, 2011).

CONCLUSION

The results indicate a positive and significant effect of salicylic acid on the properties of peanuts. According to the obtained results, it can be concluded that 70 percent of field capacity moisture and taking 3 mM salicylic acid can create a good performance in terms of quantity and quality.

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