Middle East Journal of Agriculture Research
ISSN 2077-4605
Volume : 07 | Issue : 04 | Oct.-Dec. | 2018
Pages:1411-1418

Evaluation performance of new sesame (*Sesamum indicum* L) lines under normal and drought conditions

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Received: 10 Sept. 2018 / Accepted 30 Oct. 2018 / Publication date: 15 Nov. 2018

ABSTRACT

Drought as abiotic stress is one of important constraints to sesame production. Breeding for drought tolerance in sesame is an essential mean for facing scarcity water. The objective of this study was identified drought-tolerant six sesame lines under different conditions in the field over two seasons (2016-2017). The experiments were conducted at the Agriculture Experiments and Research Station Cairo University Egypt. Six sesame lines in F_8 and F_9 generations were evaluated under normal (YP) and drought (YS) conditions. Seven drought indices including geometric mean productivity (GMP), harmonic mean (HM), stress tolerance index (STI), tolerance index (TOL), stress susceptibility index (SSI), yield stability index (YSI), and yield index (YI) were calculated based on seed yield ha^{-1}. Combine analysis based on years showed that the effect of years was insignificant for Yp, Ys and all indices except YI while interactions between lines and years were insignificant for Ys and two indices, HM and STI, indicating that these indices were more stable under different conditions. For two years, the highest seed yield ha^{-1} had recorded for line C3.8 under different conditions. Line C3.8 was higher seed yield ha^{-1} than control under drought. Three indices, GMP and HM and YI indices were selected line, C3.8 as the best drought tolerant line in two years while other indices were selected different lines during two seasons. Correlation coefficients showed that Yp was significantly and positively correlated with GMP and TOL while the negative correlation was petty with STI and YSI. Ys was significantly and positively correlated with GMP and HM. GMP showed significant and positive correlation with HM. Therefore, a combination of two indices, GMP and HM (which not affected environmental conditions) were similar to direct selection for seed yield ha^{-1} under normal condition and could be used as indicators for ridding sesame lines under drought condition. Also, line, C3.8 showed the best rank and low stander deviation than other lines during two seasons. Consequently, line C3.8 classified as the drought tolerant. Therefore, it will be recommend as a new genotype in regions suffer from drought to increase cultivated area of sesame.

Keywords: Sesame, Drought, Drought Indices, Correlation, Rank

Introduction

Egypt faces water scarcity and a severe shortage of edible oils production. Sesame is the best oil crop to cope with drought because it is able to resist water shortage compared to other oil crops. Sesame plant plays a very significant role in preserving food and nutritional security as well as livelihood improvement in developing regions of the world (Li *et al.,* 2018). Sesame is playing a role of an alternative cash crop for smallholders. Sesame contains greater oil content than other oilseeds (Eskandari and Amraie, 2015). However, drought is one of abiotic stresses which restricted cultivation sesame in arid and semi-arid areas (Islam *et al*., 2016 and Dossa *et al.,* 2017). Addition to climate change that have an even greater impact on agricultural production, particularly with regard to available freshwater for irrigation (Oosten *et al.,* 2016). The priority of plant breeders is exploiting genetic variability among genotypes to selection drought tolerant cultivars (Menezes *et al*., 2014). Dissanayake (2017) pointed that the selection of compatible varieties for drought tolerant was suitable to face this problem. For selecting drought resistant cultivars, two methods are usually utilized including grain yield as direct selection criterion and secondary traits associated with drought (Lafitte *et al*. 2003). To a certain extent, direct selection for high yield in normal condition leads to improves

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yield in stress condition (Sserumaga *et al*., 2018). Developing high -yielding varieties in drought conditions is much difficult task for breeders (Mustatea *et al.,* 2003). Therefore, drought indices were used as support method with YP and YS to determine drought tolerant genotypes (Mitra, 2001). Several selection indices have been offered for selecting new genotypes based on their effectiveness in normal and drought conditions. Estimating genotype- environment interaction is very critical to determine suitable drought indices to identify drought-tolerant lines under different conditions. A good index must be not affected by environmental conditions and correlated with yield under different conditions. Fernandez, (1992) used geometric mean productivity (GMP) to determent genotypes preferred under drought condition. Lines with high HM values were preferred under drought condition (Farshadfar and Javadinia, 2011) Fernandez (1992) proposed index called stress tolerance index (STI) to identify genotypes that produce high potential yield under normal and drought conditions. Rosielle and Hamblin (1981) pointed that stress tolerance (TOL) as the differences in yield between YP and YS since drought stress unstable in severity in field environments over years. Fischer and Maurer (1978) suggested that the stress susceptibility index (SSI) for estimation of yield stability in normal and drought conditions. Bouslama and Schapaugh, (1984) reported that higher values of yield stability index (YSI) indicates gigantic stability. To select the most desirable drought tolerant parameters, the correlations between YP, Ys, and other indices of drought tolerance were calculated which can be an advantage criterion to test the lines and indices used (Anwar *et al.,* 2011). To identify of drought tolerant lines based on a single criterion may be not enough. Therefore, rank correlation, mean rank and standard deviations of ranks for all drought indices will be used to determine the most desirable drought tolerant genotypes based on the all indices (Naghavi *et al.* (2013).The objective of this study was identified drought-tolerant lines of sesame under drought condition to increase cultivated area of sesame in Egypt.

Materials and Methods

Field experiments were conducted at the Agric. Exp. and Res. Station, Fac. Agric. Cairo Univ. Giza, Egypt, two separate experiments under normal and drought conditions during two years (15 May, 2016 and 18 May, 2017) in clay soil. Six sesame lines in F_8 and F_9 generations were evaluated in two moisture regimes. In the first, lines well-watered throughout the growing period under normal conditions. In Second, lines received adequate watering from germination to the boot stage (just before flowering stage), after which no additional watering was applied. No rain during experiment period. Lines in each experiment were layout in a randomized complete block design with three replications. The combined analysis was computed using the computer program MSTAT-C (MSTAT-C, 1991).The plots consist of 3 rows 3 m long and space 0.50 m apart with a 10 cm plant distance in the rows. The recommendations of Minstery of Agriculture applied. At harvest time, 10 plants were randomly selected in all plots then seed yield ha^{-1} under normal (Yp) and drought (Ys) conditions were estimated.

Plant Material

Breeding materials used in this investigation were 6 elite derived lines of sesame obtained via pedigree selection from a continuous breeding program that was initiated at the Agronomy Department, Faculty of Agriculture, Cairo University cooperation with Field Crops Research Department, Agricultural and Biological Division, National Research Centre (Dalia, 2001). In addition to commercial cultivar namely Shandawell 3 from Ministry of Agric. & Land Reclamation, Egypt as commercial variety. The namely of lines as follows: C1.5, C1.6, C1.8, C3.8, $C_{6.3}$ and C6.5.

Table 1: The origin, breeding status and description for parents.

Lines	Breeding status	Seed source*	Specific characters
P1(HM19)	F_8-hybrid pop	Cairo Univ.*	Early maturity, non branching first capsule set low, 3 cpsules/axil.
P2 (EUL90)	Mutant line	Cairo Univ.*	Early maturity, non-branching, first capsule set low, 3 capsule/axil.
P3 (Mutant	Mutant line	Cairo Univ.*	Branching, 3 capsules/axil.
P4 (Giza 32)	Local cultivar	Ministry of Agric.& Land Reclamation, Egypt	Heavy seed weight, medium branching, one capsule/axil, long capsule, late maturity.
P5 (NM59)	Exotic line	India through IAEA**	Stiff stem, late maturity, one capsule/axil.
P6 (Babil)	Exotic variety	Iraq through IAEA**	Low branching, 1-3 capsules/axil, semi-shattering capsules.

* Advanced breeding materials resulted from the breeding program conducted at Agron. Dept. Fac. of Agric. Cairo Univ.
** Inter. Atomic Energy Agency.

Drought indices

Seed yield ha^{-1} under normal (Yp) and drought (Ys) conditions with seven drought tolerance indices including geometric mean productivity (GMP), harmonic mean (HM), stress tolerance index (STI), tolerance index (TOL), stress susceptibility index (SSI), yield stability index (YSI), and yield index (YI), were calculated as following:

1. GMP=$\sqrt{Ys \times Yp}$, (Fernandez, 1992).
2. HM=2(Yp+Ys)/Yp+Ys, (Jafari *et al*., 2009).
3. STI=(Ys ×Yp)/$(\overline{Yp})^2$, (Fernandez,1992).
4. TOL=Y*s*-Y*p, (*Rosielle and Hamblin, 1981*)*.
5. SSI=(1-(Ys / Yp)) / (1-($\overline{Ys}$ / $\overline{Yp}$)), (Fischer and Maurer, 1978).
6. *YSI*=*Y*s/*Y*p, (Bouslama and Schapaugh, 1984).
7. *YI*=(*Ys*)/($\overline{Ys}$), (Gavuzzi *et al*., 1997).

$\overline{Yp}$ and $\overline{Ys}$ are overall mean of all lines under normal and drought conditions. The coefficients of correlation between indices were estimated by using the computer program MSTAT-C (MSTAT-C, 1991).The coefficients of correlation were tested using 'r' tabulated value at n-2 degrees of freedom at 5 % probability level, where n denote as number of lines studied. Rank correlation was calculated according to Spearman (1904) as follows: R= 1- ($6\sum D^2$/ N(N^2—1)).
Where D is rank *x* – rank *y* (i.e. the difference in the ranks) and *n* is the number of data pairs.

Results and Discussions

Combined analysis based on years for lines and drought indices were calculated. Data in Table 2 showed that the effect of years was insignificant for Yp, Ys and all indices except YI indicating that lines and almost indices were not influenced by years while lines and indices were highly significant except Ys and HM, suggesting that the lines differed from the dominant genes of seed yield and drought tolerant indices (Gholipouri *et al.,* 2009 and Yagdi and Sozen, 2009).

Estimating genotype- environment interaction is very critical to determine suitable drought indices to identify drought-tolerant lines under different conditions. The effect of interactions between lines and years were insignificant for Yp, YS, HM and STI. They were not affected by environmental conditions and were more stable than other indices. Menezes *et al*. (2014) found indices that not effected by interaction were the high values of coefficient of variability and interactions between genotypes and environment should be evaluated for selecting the best indices for genotypes ridding. Saba *et al*. (2001) and Gholipouri *et al*. (2009) reported proportionate results. If these indicators are highly significantly correlated with Yp and Ys, they could be used to identify the drought - tolerant lines. Index HM not affected with any sources of variation, therefore could be used as good indicator for identification drought resist lines of sesame.

Table 2: Combine analysis of Yp, Ys and drought indices for sesame lines

SV	df	Y p	YS	GMP	HM	STI	TOL	SSI	YSI	YI
Years	1	8648.8^{ns}	8724.8^{ns}	5569.2^{ns}	5346.1^{ns}	0.04^{ns}	0.08^{ns}	0.007^{ns}	0.011^{ns}	0.01**
L	5	57742.0**	11485.7^{ns}	29219.4**	11753.7^{ns}	0.021**	43625.4**	0.08**	0.012**	0.016**
L * Y	5	5177.3^{ns}	12293.1^{ns}	7425.6**	15062.5^{ns}	0.020^{ns}	19129.4**	0.10**	0.013**	0.023**
Error	10	6081.2	6071.3	5489.3	5478.0	0.004	540.0	0.001	0.002	0.003
CV%		5.4	7.3	6.8	7.3	8.3	5.3	2.2	2.1	5.2
M		1439.5	1008.3	1199.3	1007.4	0.73	431.1	1.0	0.72	1.0

Yp and Ys represent yield(kg/ha^{-1}) under normal and drought conditions for each line. Geometric mean productivity (GMP), Harmonic mean (HM), Stress tolerance index (STI), Tolerance (TOL), Stress susceptibility index (SSI), Yield stability index (YSI) ,Yield index (YI), SV is source of variation, L is lines, L*Y is interaction between lines and years, CV% is coefficient of variability and M is mean. ** is significant level at 5% of probability.

Mean performance of seed yield ha^{-1}

For two years, the highest seed yield ha^{-1} had recorded for lines C3.8 and C6.3 while C1.5 and C6.5 had the lowest seed yield ha^{-1} under different conditions. Line C3.8 was roughly equal to control under normal condition but under drought was higher (Table 3). Comparable results were reported by Koleva and Dimitrova (2018). The wide range in seed yield ha^{-1} for lines under normal and drought conditions showed that there variability between lines for productivity. In general seed yield ha^{-1} was significantly lower in drought condition compared to normal condition. Similar findings were reported by Urrea *et al.* (2009) and Boureima *et al*. (2016).

Comparing lines based on the tolerance indices

Drought tolerance is complex traits and many factors affect them. Therefore, drought indices were used as support method with YP and YS to determine drought tolerant genotypes (Mitra, 2001). Compatible stress tolerance indices were calculated on the basis of seed yield ha^{-1} of 6 sesame lines under Yp and Ys conditions. Seven selection indices, GMP, HM, STI, TOL, SSI, YSI and YI, were used (Table 3) for ridding of 6 sesame lines for drought tolerant.

Table 3: Tolerance indices of sesame lines under normal and drought conditions in 2016 and 2017.

				2016					
				Indices					
Lines	**Yp**	**YS**	**GMP**	**HM**	**STI**	**TOL**	**SSI**	**YSI**	**YI**
C1.5	1328.0	922.2	1106.6	925.6	0.69	405.6	1.0	0.83	0.9
C1.6	1472.2	1001	1213.7	1004.2	0.68	471.2	1.13	0.82	1.11
C1.8	1394.1	1106	1241.6	1031.2	0.79	288.8	0.70	0.89	1.12
C3.8	1778.3	1111	1405.5	1114.4	0.62	666.7	1.30	0.79	1.14
C6.3	1500.2	1028	1241.7	1109.2	0.69	472.2	1.11	0.83	1.13
C6.5	1278.2	996.1	1128.2	999.7	0.78	281.7	0.71	0.88	1.0
Con.	1760	1000.2	1326.8	1003.3	0.57	759.8	1.0	0.75	1.0
				2017					
C1.5	1321.2	1044.3	1174.5	1048.1	0.80	276.4	0.7	0.79	1.08
C1.6	1377.3	1016.2	1182.8	1019.5	0.74	361.2	0.9	0.74	1.05
C1.8	1389.4	894.7	1114.6	897.7	0.64	494.5	1.2	0.64	0.92
C3.8	1633.1	1078.1	1326.8	1081.1	0.66	555.5	1.1	0.66	1.11
C6.3	1450.2	927.8	1159.9	931.1	0.64	522.2	1.2	0.64	0.96
C6.5	1222.3	844.4	1015.9	847.8	0.70	377.8	1.0	0.69	0.87
Con.	1600.5	980.2	1252.7	983.7	0.61	620.3	1.1	0.61	1.01

Yp and Ys represent yield(kg/ha^{-1}) under normal and drought conditions for each line. Geometric mean productivity (GMP), Harmonic mean (HM), Stress tolerance index (STI), Tolerance (TOL), Stress susceptibility index (SSI), Yield stability index (YSI)Yield index (YI) and Con. is commercial variety

In 2016, two lines, $C_{3.8}$ and $C_{6.3}$ achieved the highest values of GMP, HM and YI therefore selected as the most relatively tolerant lines while other lines were selected as the least relatively tolerant lines. Since drought stress unstable in severity in field environments over years Fernandez, (1992) used GMP. Farshadfar and Javadinia (2011) pointed that lines with high GMP values were preferred under drought condition. A combination of four tolerance indices, STI, TOL, SSI and YSI were selected two lines, C1.8 and C6.5 as the most relatively tolerant lines while other lines were selected as the least relatively tolerant lines. High value of STI indicated that lines have a valuable crop and excessive drought tolerance (Rosielle and Hamblin, 1981and Rajmani.1994). low values of TOL was useful for selecting lines with high yield under drought, but flummoxed to select high yield lines under different conditions. Menezes *et al*. (2014) agreed with this opinion. Low values (less than 1) of the SSI indicated that high ability to drought tolerance (Zangi, 2005). For YSI index; higher values indicates gigantic stability, therefore two lines C1.8 and C6.5 were selected as most tolerant drought lines while line, C3.8 selected as drought sensitive lines. The reason for this the line, C3.8 was classified as high input architectures (The leaves are larger, taller plants, a higher stem height to the first capsule, three capsule node pairs, and more seed yield) in pervious breeding program therefore it was higher affected by drought than other lines. Langham (2007) classified sesame based on architectures to two basic architectures, high input and low input and in between. Worth mentioning that the line, C3.8 was classified as resistant to *two Fusarium* diseases, F. oxysporum and Macrophomina Phaseolina, (Shabana *et al*. 2014). Also, recorded higher oil yield ha^{-1} than commercial cultivars (not shown in Tables). In 2017, line, C3.8 was selected as the most relatively tolerant line based on four indices (GMP, HM, YSI and YI).Two indices, STI and TOL were selected three lines, C1.5, C1.6 and C6.5 as the most relatively tolerant lines while other lines were selected as the least relatively tolerant lines. For SSI index, two lines, C1.5 and C1.6 were selected as the most relatively tolerant lines while other lines were the other way around while STI index was selected line, C6.5 as the most tolerant lines in two seasons. In summary, three indices, GMP and HM (which not affected by environmental conditions) and YI were selected line C3.8, as the best drought tolerant line. In addition, it was higher YP than the other lines in two seasons.

Correlation analysis:

To select the most desirable drought tolerant parameters, the correlations between YP, Ys, and other indices of drought tolerance were calculated (Anwar *et al.,* 2011). Correlation analysis between YP, Ys, and drought tolerance indices can be an advantage criterion to check the lines and indices used. Mitra (2001) pointed that an ideal index must have worthy correlation with yield under normal and drought conditions. Data in Tables 4 and 5 evidenced that the YP has a petty positive association with the Ys in two seasons. Suggesting that high potential yield under normal condition does not foresee high yield under drought condition.

Table 4: Correlation coefficient between Yp, Ys and drought indices of sesame lines in 2016

Index	Yp	Ys	GMP	HM	STI	TOL	SSI	YSI
Ys	0.63							
GMP	0.92**	0.87**						
HM	0.63	0.92**	0.87**					
STI	-0.62	0.05	-0.64	-0.13				
TOL	0.83**	0.28	0.57	0.28	0.98**			
SSI	0.63	-0.18	0.30	0.09	0.94**	0.94**		
YSI	-0.51	0.25	-0.19	-0.13	0.99**	-0.84**	-0.90**	
YI	0.59	0.90**	0.79**	-0.86**	-0.05	0.22	0.01	0.54

Yp and Ys represent yield **(**kg/ha^{-1}**)** normal and yield under stress, for each line. Geometric mean productivity (GMP), Harmonic mean (HM), Stress tolerance index (STI), Tolerance (TOL), Stress susceptibility index (SSI), Yield stability index and (YSI)Yield index (YI). ** is significant level at 5% of probability levels.

Therefore, indirect selection for drought tolerance based on the performance of genotypes under normal condition would not be functional. Both Gholipouri *et al*. (2009) and Anwar *et al*. (2011) agreed with the findings. For two seasons, Yp was significantly and positively correlated with GMP and TOL while the negative correlation was petty with STI and YSI. GMP showed significant and positive correlation with HM which did not affected by environmental conditions, consequently selection for GMP and HM were similar to selection for seed yield ha^{-1} under normal condition. Also, Ys was significantly and positively correlated with GMP and HM. STI showed significant and positive correlation with TOL, SSI and YSI.

Table 5: Correlation coefficient between Yp, Ys and drought indices of sesame lines in 2017

Index	**Yp**	**Ys**	**GMP**	**HM**	**STI**	**TOL**	**SSI**	**YSI**
Ys	0.55							
GMP	0.88**	0.89**						
HM	0.55	0.99**	0.89**					
STI	-0.43	0.32	-0.06	0.32				
TOL	0.77**	-0.06	0.39	-0.06	0.78**			
SSI	0.42	-0.38	0.07	-0.39	0.85**	0.90**		
YSI	-0.23	0.48	0.10	0.48	0.92**	-0.76**	-0.92**	
YI	0.23	0.58	0.48	0.59	0.28	-0.20	-0.53	0.59

Yp and Ys represent yield (kg/ha^{-1}) normal and yield under stress, for each line. Geometric mean productivity (GMP), Harmonic mean (HM), Stress tolerance index (STI), Tolerance (TOL), Stress susceptibility index (SSI), Yield stability index and (YSI)Yield index (YI).
** is significant level at 5% of probability levels.

Therefore, a combination of two indices, GMP and HM (which not affected environmental conditions) were similar to direct selection for seed yield ha^{-1} under normal condition and could be used as indicators for ridding sesame lines under different condition.These results confirmed by Golabadi *et al.* (2006) in durum wheat, Gholipouri *et al.*(2009), Anwar *et al*. (2011) in wheat, Farshadfar *et al*. (2012 in wheat, Abdolshahi *et al*. (2013) and Koleva and Dimitrova (2018) in cotton.

Ranking of drought indices:

To identify of drought tolerant lines of sesame based on a single criterion may be not enough (Naghavi *et al*. (2013). Rank, mean rank and standard deviations of ranks for all drought indices were calculated (Table 6) to determine the most desirable drought tolerant sesame lines based on the all indices.

Results indicated that two lines, C3.8 and C6.3 were the best rank and low SD than other lines during two seasons, consequently classified as the most drought tolerant lines. These lines could used as parents in other programs for drought tolerant. While line, C6.5 was in contrast and classified as the most sensitive. Other results supported these results (Farshadfar *et al.,* 2012; Khalili *et al.,* 2012 and Naghavi *et al.,* 2013).

Table 6: Rank, ranks mean (RM) and standard deviation of ranks (SD) of drought tolerance indices for six promising sesame lines in two seasons.

Entry	**C1.5**		**C1.6**		**C1.8**		**C3.8**		**C6.3**		**C6.5**	
Years	16	17	16	17	16	17	16	17	16	17	16	17
Yp	5	5	3	3	4	2	1	1	2	4	6	6
YS	6	4	4	5	3	3	1	1	2	2	5	6
MGP	6	5	4	6	3	4	1	1	2	2	5	3
HM	5	2	4	3	3	4	1	1	2	2	5	6
STI	2	1	5	4	1	5	3	2	4	3	6	6
TOL	6	2	4	5	2	6	3	4	2	3	1	1
SSI	4	5	5	6	1	1	2	2	3	3	6	4
YSI	4	1	3	5	5	4	1	2	2	3	6	6
YI	4	5	5	5	4	3	1	1	2	2	3	6
R	4.7	3.3	4.1	4.7	2.9	3.6	1.6	1.7	2.3	2.7	4.8	4.9
SD	1.3	1.8	0.8	1.1	1.4	1.5	0.9	1.0	0.7	0.7	1.7	1.8

Yp and Ys represent yield normal and yield under stress, for each line. Geometric mean productivity (GMP), Harmonic mean (HM), Stress tolerance index (STI), Tolerance (TOL), Stress susceptibility index (SSI), Yield stability index and (YSI)Yield index (YI). 16: 2016 and 17:2017 seasons. R is rank mean and SD is stander deviation.

Conclusion

Final product from this study was line, C3.8 which recorded the highest seed yield ha^{-1} than other lines and control under drought condition in the field over two seasons (2016-2017). And classified as drought –tolerance line based on two drought indices, GMP and HM and Ys. Also, recorded the highest rank and low SD. Therefore, C3.8 will be recommend as a new genotype that could be used as a parent in other breeding program for drought - tolerant.

Acknowledgment to the National Research Center in Egypt for funding this study. Many thanks to my supervisors Prof. Mohamed Reda Ali Shabana and Prof. Adel Abdel Moneim Hoballah, department Agronomy, Faculty of agriculture, Cairo University, for their continuous guidance and scientific support and advice for me. Special thank to Prof. Adel Abdel Moneim Hoballah for the development of plant materials.

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