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Morpho-agronomical Diversity in Some Sesame (*Sesamum indicum* L.) Cultivars under Drought Stress Conditions

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Authors' contributions

This work was carried out in collaboration between both authors. Author MS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author SMJ managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Sesame (*Sesamum indicum* L.) is a survivor crop. It is one of the most important oilseed crops. Despite of its tolerance, drought is one of the most important environmental factors that limit sesame production. Iran has an arid and semi-arid climate and very fertile lands for agriculture that the main factor limiting production is their lack of water. In this study, the experimental treatments consisted of irrigation levels as the main plot at four levels and fifteen cultivars of Sesame as the subplot was considered. Morpho-agronomic traits such as plant height, number of capsules per plant, seed number/capsules, weight of 1000 seeds, number of branches, grain yield, number of leaves per plant, biomass, and oil content were recorded. The study of analysis of variance (ANOVA) showed significant differences at $P<0.01$and $P<0.05$ among cultivars and irrigation levels for all traits. Results of Duncan's test indicated that Darab14, TS3, Halil, Yellow, white and JL13 cultivars were found to be the best cultivars for normal and drought stress conditions. Genetic diversity was also studied based on various Morpho-agronomical traits using analysis of cluster and principal component analysis among studied cultivars. Analysis of cluster indicated that the

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cultivars were divided into three major groups. Some of the cultivars (first group) performed better than the others and were ranked higher. In other hand, in the principal component analysis, the first and second principal components showed 89.93% of total variation. The bi-plot of PC1 and PC2 identifies that the cultivars of JL13, TS3, Darab14, Halil, Bampour and Oltan, as closely related and distinctly separated from other cultivars. Therefore, these traits have good potential for selection of cultivars. The selected cultivars can be used in crossing together for creating genetically variation or for the direct cultivation of tolerant cultivars.

Keywords: Sesame; drought stress; cluster analysis; morpho-agronomical traits; principal components.

1. INTRODUCTION

Sesame (*Sesamum indicum* L.) is a survivor crop. It is one of the most important oilseed crop [1]. Iran has an arid and semi-arid climate and very fertile lands for agriculture that the main factor limiting production is their lack of water[2]. Sesame is grown in many regions of the world and mainly grown in tropical and subtropical regions of Asia, Africa, and South America, in marginal lands or under very difficult conditions with drought, high temperatures, high solar radiation, and high evaporation demand which make sesame a drought tolerant plant [1,3]. Around 80% of the world production, i.e. over 3.2 million tons, is coming from the main sesame growing countries: India, China, Myanmar, Sudan, Uganda, Nigeria, Ethiopia, Pakistan, and Bangladesh [4,5].

Sesame seeds contain greater oil content than that of other oilseeds, that contain 37 to 63% of oil and 17-32% of protein (rich in Sulphur-containing amino acids). Around 80% of Sesame oil is composed of unsaturated fatty acids [6,7]. Despite its tolerance, drought is one of the most important environmental factors that limit sesame production by affecting the number of capsules per plant, grain yield as well as oil yield and quality depending on the genotypes and drought intensity [8,9,10]. Cultivation of drought-tolerant crops is a useful strategy inefficient use of limited water. Therefore, improvement of drought tolerance in sesame genotypes is one of the major objectives of sesame breeding programs which can be achieved by integrating new approaches [11]. For screening of drought-tolerant crops cultivars, some scientists have suggested a two-stage selection procedure. In the first stage, the genotypes are screened based on yield performance under drought stress conditions. The second stage of screening takes place within the selected genotypes of the first stage, based on morphological traits associated with drought tolerance [12].

Genetic variation exists for vital agronomical characteristics in sesame. Therefore, a more useful and reliable tool is required to, infer genetic relationships among different collections of sesame in order to facilitate the current breeding efforts for grain yield and oil quality improvement [13].

Traditionally, studies of genetic characterization and divergence are based on morphological markers and quantitative traits. Breeding efforts so far have concentrated on characterization and cataloging of germplasm collections using only morpho-agronomical traits [14].

Traditional sesame landraces, as well as related wild species, are an important source of genetic diversity for breeders. The success of plant breeding depends on the extent of genetic variability present in the crop. However, the development of improved plant cultivars is restricted mainly due to the narrow genetic pool which results in the limited possibility to restructure the sesame crop. Potential of yield under stress is not the best measure for drought tolerance. However, performance and stability are introduced as criteria to compare the normal and stress conditions. Drought stress caused a significant reduction in grain yield, biomass, and harvest index. Multiple markers for genotyping reaction to stress are presented [2,15]. It was also reported that there could be many genetic and environmental factors on plant yield in [16].

However, there is limited information on the diversity of sesame genetic resources. Also, the possibility of using such resources for developing high-yielding and drought-tolerant sesame varieties is limited. Researchs on Sesame in recent years has continued with more consistency and other recommendations in the cultivation and identification of genotypes adapted to drought conditions. Some sesame breeding lines were evaluated using common quantitative indices of stress tolerance, suggesting the usefulness of these indices for evaluation of sesame germplasm for drought tolerance [17].

The present study was conducted to identify the best drought-tolerant cultivars forusing in sesame breeding programs. The purpose of the present study is to determine the responses of sesame cultivars of different origins to drought stress and consequently identify drought-tolerant lines or cultivars in arid and semi-arid regions of Iran. Selected sesame cultivars from different regions of Iran, India, and China were evaluated under normal irrigation and drought stress (limited irrigation) conditions and were comparatively analyzed the diversity of drought tolerance in sesame cultivars.

2. MATERIALS AND METHODS

Fifteen Sesame (*Sesamum indicum* L.) cultivars were collected from different geographical regions of Iran and were transferred and planted in the farmland of Iranshahr Islamic Azad University(latitude 27.12°N, longitude 60.24°E, Altitude 591 m above sea level) in July 2016. The Sesame cultivars were grown in a split-plot basis of randomized complete block design with three replications.

The experimental treatments consisted of irrigation levels as the main plot at four levels (irrigation after 50, i.e. normal irrigation, 100, 150 and 200 mm evaporation from evaporation pan of class A) and fifteen cultivars of Sesame as the sub plot was considered in this study. Each plot contained 3 rows with 60cm distance and 3m in row length. All plots were irrigated after sowing and subsequent irrigations at the beginning of stem elongation. Weeds were controlled by hand during crop growth and development.

At maturity stage, Morpho-agronomical characteristics or traits such as plant height (cm), number of capsules per plant, means of seed number/capsules, weight of 1000 seeds (g), number of branches, grain yield (g), number of leaf per plant, biomass and oil content were recorded in Sesame cultivars for comparative studies. Morpho-agronomical data were subjected to analysis of variance (ANOVA) using statistical analysis system and followed by Duncan's multiple range tests and terms were considered significant at $P<0.05$ and $P<0.01$ by SPSS software version 22 and MSTATC software. Data matrices were constructed with individuals (15) as columns and characteristics (9) as rows. The data matrices were then subjected to multivariate methods as cluster analysis (using average linkage between groups) and principal component analysis by SPSS software version 22.

3. RESULTS AND DISCUSSION

According to our experiments, the study of analysis of variance showed highly significant differences at $P<0.01$ among cultivars for all traits, except a number of branches and biomass which were significant in probability level $P<0.05$. The difference at $P<0.01$ among normal irrigation and drought stress conditions, 50 (normal irrigation), 100, 150 and 200 mm evaporation from evaporation pan of class A", was significant for all of the traits, except number of leaf/plant and biomass which were significant in probability level $P<0.05$. There were also highly significant differences at $P<0.01$ among interaction effects for all traits (Table 1). This study indicated that the magnitude of differences in cultivars and interaction effects were sufficient to select them against drought. Therefore, these traits have good potential for selection of the most tolerant and most sensitive cultivars. The selected cultivars can be used in crossing together for creating genetically variation or for direct cultivation of tolerant cultivars. Similar results were reported in [18,19].

Results from Duncan's test indicated that Darab14, TS3, Halil, Yellow white and JL13 cultivars were found to be the best cultivars for normal irrigation and drought stress conditions. Maximum amounts number of capsules/plant, mean of seed number/capsules and grain yield traits were recorded for Darab14 and JL13 cultivars. Maximum amounts for plant height, number of leaf/plant, biomass and weight of 1000 seedstraits were recorded for JL13 cultivar. Maximum oil contentwere recorded for Darab14 cultivar in normal irrigation and drought stress conditions. Furthermore, maximummean of seed number/capsules and number of branches traits in drought stress conditions for the JL13 cultivar and normal irrigation for Darab14 and Yellow white cultivars were recorded.

Phenotypic correlations between various Morpho-agronomical traits indicated that there were significant correlations at $P<0.05$ or $P<0.01$ among the most studied traits (Table 2). Similar results were reported in [3,20,21]. For example, highly significant positive correlation were observedat $P<0.01$ among the plant height and all the studied traits except number of branches per plant and weight of 1000 seeds. Also, highly significant positive correlation were observedat P<0.05 among weight of 1000 seeds with biomass and oil content with number of branches, number of leaf/plant and biomass. Moreover, a highly significant were observed negative correlation at P<0.05 or P<0.01 among the number of branches per plant with weight of 1000 seeds and plant height, weight of 1000 seeds with number of capsules/plant and mean of seed number/capsules. Phenotypic correlations among traits indicated that some associated factors correlate with each other and contribute in the occurring of these traits [21,22]. Sesame cultivars were more separated by the help of their capsules size and capsules shape traits. Although, common Sesame cultivars exhibited some variations in plant height, oil content, number of capsules per plant and etc., these could be attributed to the adaptations of their original geographical and environmental conditions. Complete phenotypic expression of Morpho-agronomical traits that show variations, makes the identification easier. Moreover, Morpho-agronomical traits cannot alone determine the roles of phenotypic plasticity and genetic differentiation on population variation and adaptation. Hence, they lack the sufficient resolving power needed to identify cultivars diversity [20,21].

Genetic diversity was studied based on various Morpho-agronomical traits using analysis of cluster among studied Sesame cultivars. Dendrogram using average linkage (between groups) indicated that the cultivars were divided to three major groups (Fig. 1), the first group divided into two clusters (consist 6 and 2 cultivars, respectively), the second group contained two cluster (consist 3 and 2 cultivars, respectively) and the third group divided into one clusters (consist 2 cultivars).

JL13, TS3, Darab14, Yellow-white, Halil, Moghan17, Bampour and Oltan cultivars were in the first group. The most cultivars were in this group. Iranshahr, Shahdad, India, China and Naz cultivars were in the second group. Also, Yekta and Varamin2822 cultivars were in the third group. The mean of studied traits for the third group cultivars was lower than one of the second group and the best cultivars were in the first group. This clustering indicated that there were differences among cultivars in normal irrigation and drought stress conditions. Some of the cultivars (first group) performed better than others and were ranked higher; whereas the cultivars in the second and third group have worse performance than ones in the first group and were ranked lower. Similar conclusion were reported in [21,23].

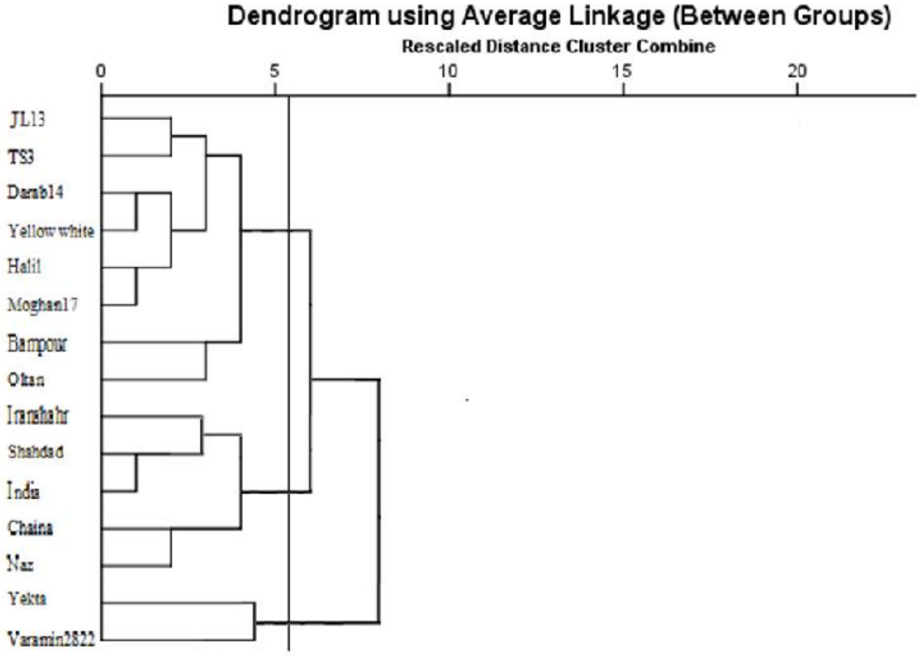

Fig. 1. Cluster analysis dendrogram of Sesame cultivars based on studied traits

Table 1. Variance analysis of studied traits in Sesame cultivars

Source of variation	**Degree of freedom**	**Plant height**	**Number of capsules/ plant**	**Mean of seed number/ capsules**	**Weight of 1000 seeds**	**Grain yield**	**Number of branches**	**Number of leaf/plant**	**Biomass**	**Oil content**
Replication	2	845.63^{ns}	423.99^{ns}	65.67^{ns}	0.78^{ns}	1786.96^{ns}	904.87^{ns}	673.56^{ns}	61970.56^{ns}	512.41^{ns}
Irrigation	3	5447.21^{**}	5407.81^{**}	356.78^{**}	5.30^{**}	6901.30^{**}	4325.32^{**}	4326.22^{*}	267435.21^{*}	1599.04^{**}
Error(a)	6	523.45	210.18	27.45	0.21	453.45	321.45	578.45	43654.34	134.49
Cultivars	14	456.11^{**}	920.30^{**}	80.01^{**}	1.69^{**}	464.21^{**}	554.32^{*}	543.43^{**}	83432.16^{*}	451.64^{**}
Interactions	42	567.09^{**}	187.69^{**}	78.65^{**}	0.59^{**}	568.47^{**}	534.61^{**}	299.23^{**}	87569.59^{**}	374.18^{**}
Error(b)	112	235.75	98.79	31.11	0.25	295.75	278.05	135.75	42354.05	164.75
Coefficient of variation %		10.05	19.29	12.4	14.15	16.43	9.56	13	11.20	10.23

*ns, * and **: non-significant, significant in 0.05 and 0.01 level, respectively*

Table 2. Phenotypic correlation of studied traits in Sesame cultivars

	Plant height	**Number of capsules/ plant**	**Mean of seed number/ capsules**	**Weight of 1000 seeds**	**Grain yield**	**Number of branches**	**Number of leaf/plant**	**Biomass**	**Oil content**
Plant height	1								
Number of capsules/ plant	0.89**	1							
Mean of seed number/capsules	0.95**	0.79**	1						
Weight of 1000 seeds	0.44*	-0.34*	-0.83**	1					
Grain yield	0.94**	0.94**	0.96**	0.68**	1				
Number of branches	-0.79**	0.91**	0.89**	-0.74**	0.78**	1			
Number of leaf/plant	0.96**	0.89**	0.90**	0.75**	0.92**	0.87**	1		
Biomass	0.74**	0.97**	0.83**	0.53*	0.83**	0.97**	0.95**	1	
Oil content	0.79**	0.91**	0.91**	0.89**	0.89**	0.51*	0.44*	0.35*	1

*ns, * and **: non-significant, significant in 0.05 and 0.01 level, respectively*

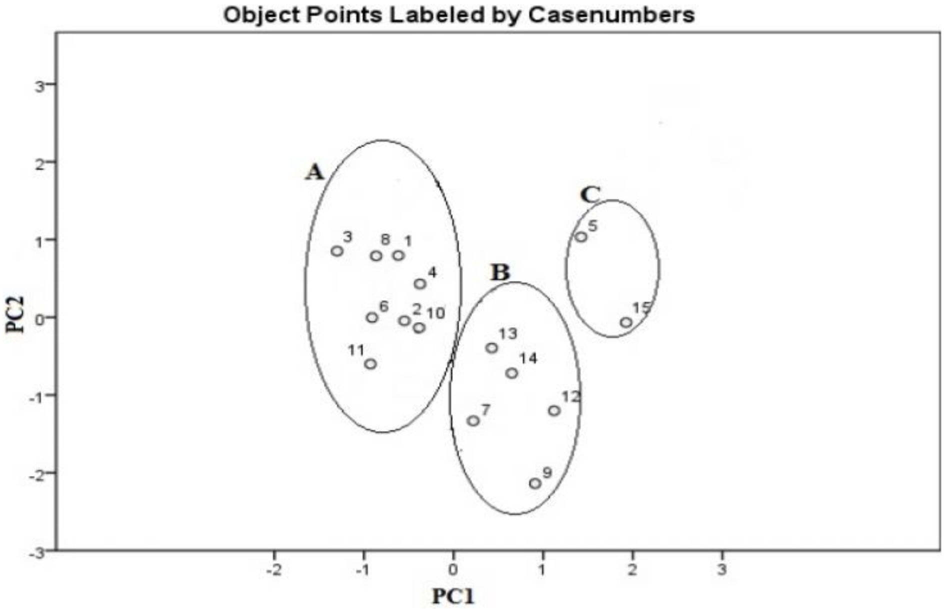

Fig. 2. Biplot of principal coordinate analysis of Sesame cultivars based on studied traits

In the principal component analysis, the first and second principal components showed 89.93% of total variation. The bi-plot of PC1 and PC2 (Fig. 2) identifies cultivars of JL13, TS3, Darab14, Yellow-white, Halil, Moghan17, Bampour and Oltan, as closely related and distinctly separated from other cultivars. These results indicate that Iranian cultivars may share the same origin with sesame cultivars of the other regions.

JL13, TS3, Darab14, Yellow-white, Halil, Moghan17, Bampour and Oltan cultivars were in the first group. The most cultivars were in this group. Iranshahr, Shahdad, India, China and Naz cultivars were in the second group. Also, Yekta and Varamin2822 cultivars were in the third group.

Therefore, synchronic application of all these indices can provide more reliable estimation than using each index independently for drought tolerance in sesame. Hence, performing a multivariate analysis, such as cluster analysis and PCA will be more appropriate than other analysis methods for distinguishing drought-tolerant genotypes. Similar results were reported in [11,21].

4. CONCLUSION

In this paper, genetic diversity was studied based on Morpho-agronomical traits. Although common Sesame cultivars exhibited some variations in plant height, oil content, a number of capsules per plant and etc., these could be attributed to the adaptations of their original geographical and environmental conditions. However, cluster analysis and PCA indicated that there were differences among cultivars. The clustering indicated that there were differences among cultivars in normal irrigation and drought stress conditions. Some of the cultivars (first group) performed better than others and were ranked higher; whereas the cultivars in the second and third group have worse performance than ones in the first group and were ranked lower. Also, phenotypic correlations among traits indicated that some associated factors correlate with each other and contribute to the occurring of these traits. This study indicated that the magnitude of differences in cultivars and interaction effects were sufficient to select them against drought. Also, results indicated that there is a high variation for all traits which revealed the presence of genetic diversity for these attributes in the materials. Therefore, these traits have good potential for selection of the most tolerant and most sensitive cultivars. The selected cultivars can be used in crossing together for creating genetically variation or for the direct cultivation of tolerant cultivars.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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