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Inheritance Studies of Morphological Characteristics in Okra (*Abelmoschus esculentus* L. Moench) Under Drought Conditions

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Abstract. The present studies aimed at assessing the inheritance pattern of morphological characteristics i.e. days taken to flower, days taken to maturity, fresh fruit yield per plant, 100-seed weight and seed yield per plant of okra (*Abelmoschus esculentus* L. Moench) under normal and water stress conditions to explore drought tolerant genetic sources. Three genotypes viz. DLPG × Parbhani Karanti, No. 8 × Green Velvet and Parbhani Karanti × Green Velvet were evaluated under normal (T1) and drought (T2) conditions to assess the trend of inheritance. In T1, weekly irrigation was given and in T2 three consecutive irrigations were skipped out at flowering and podding stage. No response of water stress was observed in heterosis, inbreeding depression and potence ratio for days taken to maturity. However, the combinations exhibited differential behavior for days taken to flower, fresh fruit yield per plant, 100-seed weight and seed yield per plant of okra due to water stress.

Keywords: okra, inheritance studies, drought conditions

Introduction

Drought is worldwide problem posing a serious threat to agricultural productivity. Drought describes a condition in which available soil moisture is reduced to a level where plant growth is severly affected (Osmanzai *et al.*, 1987). It influences growth by affecting cell elongation directly and more indirectly mineral uptake and allocation and especially photosynthesis (Hsiao, 1973). Most of the vegetables are sensitive to drought as compared to other crops possessing fibrous root system. Okra being malvaceous has tapped root system. Therefore, its ability to tolerate drought is comparatively high. Okra is much popular as vegetable grown in all the provinces of Pakistan in both crop seasons (spring and summer). Nutritionally, it contains protein, thiamin, niacin, vitamin C and energy. Medicinally, mucilage from fruit and seed is used as demulcent, emollient, laxative and diuretic.

Drought causes 70% reduction in fruit yield of okra during flowering stage (Mbagwa and Adesipe, 1987). It is the critical stage for this plant. Therefore, the effective solution of this problem is to breed drought resistant/tolerant plants (Blum, 1979). Progress in plant breeding for drought resistance has been limited due to two major problems. First, drought is a complex attribute of a crop community (Blum, 1979) and it is not clear how specific mechanisms at the tissue or organ level are integrated in determining yield under water stress. (Hsiao and Bradfor, 1983).

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Hybrid vigour in the first generation (F_1) generally reflects potentiality of its segregates in succeeding generations. Ahmad *et al.* (2004) and Kumar *et al.* (2006a,b) had pointed out that the heterosis observed in okra du to genetic interaction and overdominance. Therefore, development of hybrid the F_1 cultivar is the best way to expolait gain observed in generation. Generally, the crosses manifesting good heterotic expressions in F_1 are likely to give better segregates when non-additive genetic effects are low. Genetically, heterosis refers to increase or decrease of F_1 value over the means, of parent value (Matzinger *et al.*, 1962). From breeders point of view, the increase of F_1 value over the better parents was observed (heterobeltiosis) is more important (Fonseca and Patterson, 1968). Kumbhani *et al.* (1993), and Shukla *et al.* (1989) reported highest heterosis over the better parents for number of pods per plant and seed yield per plant. Significant heterosis over better parent for yield per plant in pigeon pea was reported by Khorgade *et al.* (2000), and number of bolls and seed cotton yield in cotton observed by (Rajan *et al.* (2000).

Materials and Methods

The experiment was conducted at Central Cotton Research Institute, Multan, Pakistan. The purpose of the experiment was to estimate the genetic parameters in okra under drought conditions and to evolve drought tolerant varieties by adapting suitable breeding strategies. For this purpose, six varieties namely; Chinese Red, Clemson Spineless, Dwarf Long Pod Green (DLPG), Parbhani Karanti, Green Velvet, No. 8 × Green Velvet and Parbhani Karanti × Green Velvet showed higher fruit and seed yield per plant were selected for drought studies. Two treatments (T_1 and T_2), T_1 as normal and T_2 as drought were used. In T_2, three consecutive irrigations were skipped out at flowering and podding stage. The seeds of these crosses were sown on both sides of ridges in order to obtain F_1 population. Nitrogen at the rate of 80 kg/ha in the form of urea and 65 kg P/ha in the form of super phosphate was added as basal dose. At flowering and podding stage, 80 kg N/ha in the form of urea was also applied in two split doses. Triplicated randomized complete block design was used by keeping interrow and interplant distance as 75 and 20 cm, respectively. Recommended insecticides i.e. methamedophos, chlorpyrifos and diafenthiruon were applied against insects. Thinning was done among the genotypes by keeping 40 plants at proper distance. Data of 30 plants were recorded for days taken to flower, days taken to maturity, fresh fruit yield per plant, number of pods per plant, 100-seed weight and seed yield per plant. Statistical analysis was carried out through "MSTATC" statistical package on computer to test the significance. Heterosis in F_1 was estimated by using the formula given by Millar and Marani (1963) as under:

$$\text{Heterosis} = \frac{\overline{F}_1 - \overline{MP} \times 100}{MP}$$

Where:

F_1 = the mean value of F_1 and

MP = the mean mid parent value.

Dominance estimates were determined for each trait using potence ratio method proposed by Griffing (1956).

$$Hp = (\overline{F}_1 - \overline{MP}) / (\overline{P} - \overline{MP})$$

Where:

Hp = the dominance estimates which measures the degree of dominance of each trait.

Inbreeding depression was measured as describe by Millar and Marani (1963).

$$\text{Inbreeding depression} = F_1 - F_2 / F_1 \times 100$$

The significance of heterosis and inbreeding depression was tested by calculating critical difference (CD) by the following formula:

$$CD = S.E \times 100$$

Where:

S.E. is standard error of the difference of crosses and equal to $\sqrt{2EMS/r}$

Results and Discussion

Days taken to first flower. Negative heterosis was observed in the cross DLPG × Parbhani Karanti in both treatments. In this case, highly significant ($P < 0.01$) heterosis (-4.40%) in the cross No. 8 × Green Velvet was changed into negative heterosis (-4.40%) under water stress conditions (Table 1 and 2). Negative heterosis due to stress in the crosses provides evidence that genes for days taken to first flower are acting towards the direction of lower parent. The magnitude of highly significant ($P < 0.01$) inbreeding depression in the cross Parbhani Karanti × Green Velvet increased to some extent under stress conditions. All the combinations showed incomplete dominance in both normal and stress treatments.

As a whole crosses showed sensitivity to drought for heterosis and resistance for inbreeding depression. Positive partial dominance was altered into negative incomplete dominance due to water stress in the crosses No. 8 × Green Velvet and Parbhani Karanti × Green Velvet.

Fresh fruit yield per plant. In normal conditions (T_1), significant ($P < 0.05$) heterosis (71.13%, 43.96% and 37.53%) was estimated in cross combinations i.e. Parbhani Karanti × Green Velvet, No. 8 × Green Velvet and DLPG × Parbhani Karanti, respectively. The higher inbreeding depression (13.54%) for this trait was exhibited by the cross Parbhani Karanti × Green Velvet (Table 1). Over dominance ranging from 1.93 to 6.33 was observed in the crosses. But in water stress conditions, non significant heterosis with decreased amount of inbreeding depression resulted for the traits in the crosses, DLPG × Green Velvet and Parbhani Karanti × Green Velvet. Contrary to that, significant (PL 0.05) heterosis with increased inbreeding depression was observed in the cross No. 8 × Green Velvet under stress conditions. Positive and high heterosis in okra has been observed by the earlier researchers like; Bendale *et al.* (2004), Pawar *et al.* (1999) Kumbhani *et al.* (1993), Sivagamasundhari *et al.* (1992), Mandal and Das (1991), Sarnaik and Singh (1990), and Poshiya and Shukla (1986).

Dominance in normal conditions was changed to partial dominance in the crosses, DLPG × Parbhani Karanti and Parbhani Karanti × Green Velvet due to water stress. On the other hand, value of the over dominance of the cross No. 8 × Green Velvet was increased at greater extent by giving water stress.

Being a vegetable, fresh fruit yield of okra is a character of immense importance as compared to seed yield and breeders have been endeavoring for its improvements along with other traits through different breeding strategies. In the present studies, the combination DLPG × Parbhani Karanti under both conditions and Parbhani Karanti × Green Velvet under stress conditions exhibited negative inbreeding depression. The negative inbreeding depression in the crosses indicates the presence of transgressive segregates in F_2. Any heterosis found in such combinations will be expected to persist for further generations which could be utilized for the synthesis of a new variety. On the other hand, positive inbreeding depression in the cross No. 8 × Green Velvet under both conditions and the cross Parbhani Karanti × Green Velvet under normal conditions indicate the absence of transgressive segregants in F_2, suggesting the usefulness of selection in first generation hybrids. The combination No. 8 × Green Velvet showed high value of heterosis under drought conditions which indicates that selection in later generations will be effective to get desirable drought resistant lines.

Days taken to maturity. Negative heterosis accompanied by incomplete dominance was observed in all the three crosses in both treatments (Table 1 and 2). Generally low heterosis and inbreeding depression values points to the presence of additive gene action thus giving way to simple selection for its improvement. No prominent effect on heterosis and dominance was exhibited by the crosses due to water stress. Considerable tolerance to drought in this respect was shown as non-significant by the crosses. Positive inbreeding depression were increased due to Green Velvet. Positive inbreeding depression for this trait in the cross DLPG × Parbhani Karanti under both conditions and the cross Parbhani Karanti × Green Velvet under stress conditions was observed.

Number of pods per plant. The combinations DPLG × Parbhani Karanti and No. 8 × Green Velvet showed highly significant ($P < 0.01$) heterosis under normal conditions (Table 1). But magnitude of heterosis was decreased due to stress in the cross DLPG × Parbhani Karanti and increased in the cross No. 8 × Green Velvet showing highly significant heterosis (Table 2). On the other hand, heterosis and inbreeding depression was observed under normal conditions in the cross Parbhani Karanti × Green Velvet. However, positive heterosis with negative inbreeding depression was observed in the cross under stress conditions. In all the crosses, negative inbreeding depression was estimated except the cross No. 8 × Green Velvet having highly significant value (24.49%) (Table 1). Due to stress, the combinations DPLG × Parbhani Karanti and No. 8 × Green Velvet having complete and partial dominance under normal conditions showed over dominance under stress conditions. Complete dominance was observed by Partap and Dhankar (1980) in okra for number of fruits per plant. Generally, the cross No. 8 × Green Velvet gave satisfactory result under drought conditions by showing significant heterosis and resistance of inbreeding depression. Positive heterosis indicates the presence of non-additive gene effects for number of pods in No. 8 × Green Velvet cross suggesting the usefulness of selection in first generation hybrids. The negative magnitude of inbreeding depression in mostly all the crosses indicates the presence of transgressive segregants in F_2. Any heterosis found in such combinations will be expected to persist for further generations which could be utilized for the synthesis of a new variety. The above results are in agreement with those of Sivagamasundhari *et al.* (1992), Mandal and Das (1991), Poshiya and Shukla (1986).

Table 1. Estimates of heterosis, potence ratio and inbreeding depression for various plant characteristics in three okra crosses under normal conditions (T_1)

Crosses	Inheritance parameters	Days taken to first flower	Days taken to maturity	Fresh fruit yield per plant (g)	Number of pods per plant	100-seed weight (g)	Seed yield per plant (g)
DPLG × PK	Heterosis (%)	-2.51	37.53*	-4.08	22.12*	15.67*	-9.61
	potence ratio	-0.41	1.93	-0.62	1.00	1.60	-0.17
	inbreeding depression (%)	12.68*	-25.71	1.60	-46.4	1.92	-66.79
No. 8 × GV	Heterosis (%)	4.40*	43.96	-4.91	8.44**	4.66**	8.99**
	potence ratio	0.37	5.09	-0.93	0.85	0.68	0.50
	inbreeding depression (%)	7.92**	3.30	-1.15	-2.63	-21.12	-61.37
PK × GV	Heterosis (%)	0.61	71.13**	-2.65	-	23.44**	-42.74
	potence ratio	0.07	6.33	-0.56	-	3.00	-1.89
	inbreeding depression (%)	4.68	13.54	-1.49	-23.4	2.53**	-120.12

* = means differ significantly at only 5% probability level; ** = means differ highly significantly at both 1 and 5% probability levels

Table 2. Estimates of heterosis, potence ratio and inbreeding depression for various plant characteristics in three okra crosses under stress conditions (T_2)

Crosses	Inheritance parameters	Days taken to first flower	Days taken to maturity	Fresh fruit yield per plant (g)	Number of pods per plant	100-seed weight (g)	Seed yield per plant (g)
DPLG × PK	Heterosis (%)	-4.45	7.45	-3.49	18.96**	35.22**	-20.53
	potence ratio	-0.59	0.31	-0.59	1.13	54.14	-0.52
	inbreeding depression (%)	9.90**	-37.78	2.92	-16.35	12.03**	-74.17
No. 8 × GV	Heterosis (%)	-4.44	71.37**	-3.28	12.26	-5.19	-4.51
	potence ratio	-0.36	35.33	-0.84	1.23	-0.82	-0.11
	inbreeding depression (%)	10.44**	13.49	-0.90	24.49**	-45.44	-61.62
PK × GV	Heterosis (%)	-0.71	5.93	-0.37	1.67**	15.60	-45.72
	potence ratio	-0.07	0.29	-0.08	0.12	10.62	-12.18
	inbreeding depression (%)	4.28	-39.00	0.87	-33.49	3.65**	-185.26

** = means differ highly significantly at both 1 and 5% probablity levels

100-seed weight. All the crosses showed highly significant ($P < 0.01$) positive heterosis under normal conditions for this trait. By imposing water stress, increased highly significant heterosis (35.22%) with highly significant ($P < 0.01$) and increased inbreeding depression (12.03%) was estimated in the cross DPLG × Green Velvet (Table 1). On the other hand, NO. 8 × Green Velvet showed negative heterosis by giving water stresses. In this case, positive heterosis (4.66%) was converted into negative heterosis (-5.19%) due to stress. The cross Parbhani Karanti × Green Velvet showed highly significant heterosis (23.4%) and 15.60%) (Table 1 and 2) under normal and water stress conditions, respectively. But increase in inbreeding depression (2.53 to 3.65%) was estimated due to stress. In normal conditions, non-significant inbreeding depression (1.92%) of the cross DPLG × Green Velvet was changed into highly significant inbreeding depression by imposing stress. The magnitude of highly significant ($P < 0.01$) inbreeding depression under normal conditions was increased under stress in the cross Parbhani Karanti × Green Velvet.

Over dominance in the crosses DPLG × Parbhani Karanti and Parbhani Karanti × Green Velvet was estimated in both treatments. Positive partial dominance with No. 8 × Green Velvet was estimated in the normal conditions and negative in water stress conditions. Positive heterosis for seed index in cotton was observed by Dani and Kohel (1989).

Seed yield per plant. Under normal conditions, a positive highly significant ($P < 0.01$) heterosis (8.99%) is evident in the combination No. 8 × Green Velvet (Table 1). But by giving water stress, the positive heterosis was changed into negative heterosis. In this case, the direction of gene activity is towards lower parent. All other combinations showed negative heterosis accompanied by negative inbreeding depression under both conditions. The combinations No. 8 × Green Velvet and DLPG × Parbhani Karanti exhibited partial dominance under both conditions. But over dominance was shown by Parbhani Karanti × Green Velvet under both conditions. In this case, all the crosses showed resistance to stress for this parameter.

Okra is a vegetable and plant breeders are doing their best to get more fresh fruit as compared to seed yield per plant. But, unfortunately when they increase fresh fruit weight, seed yield is decreased. Moreover, vegetarians do not like okra pods with more number of seeds. Therefore, they are facing problems to combine these both traits. Negative heterosis indicated these facts under both conditions. Many scientists like Kumbhani *et al.* (1993), Mandal and Das (1991) and Sivagamasundhari *et al.* (1991)observed higher and considerable heterosis under normal conditions.

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