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NATURE AND MAGNITUDE OF GENETIC VARIABILITY, HETEROSIS AND INBREEDING DEPRESSION IN *AMARANTHUS*

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Combining ability, heterosis and inbreeding depression were estimated in grain amaranths for ten characters. Non- additive genetic variance was predominant for majority of characters in both F_1 and F_2 generations. The parent AG-21 was good general combiner for yield/plant also showed high gca effects for panicles/plant and harvest index in both F_1 and F_2 generations. Seven characters, the best F_2s on the basis of sca involves one parent with high gca effect and the other with poor or average gca effects. The hybrids which exhibited highest heterosis also showed high inbreeding depression. Heterosis over better parent was highest for economic grain yield (145.047%), followed by panicles/plant (113.675%), panicle length (33.656%) and grain weight/panicle (23.566%).

Key words: Grain amaranths, combining ability, heterosis, inbreeding depression.

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INTRODUCTION

Grain amaranths of the genus *Amaranthus* contains about 20 species (wild and cultivated types) distributed throughout the world (SAUER, 1967). There are three species of grain amaranths which produce large seed heads of edible, light coloured seeds. *A. cruentus* L. and *A. hypochondriacus* L. are native of Mexico and Guatemala and *A. caudatus* is native to the Andean regions of Ecuador, Peru and Bolvia (SAUER, 1967). Among these *A. hypochondriacus* is cultivated throughout the world for its seeds occupies an important position among the pseudocereals due to its high yield and protein content (BERGHOFER and SCHOENLECHNER, 2002). In India the species is widely cultivated for its seed from Kashmir to Arunachal Pradesh. It is an out-inbred crop, upto 40% outcrossing depending upon the varying environmental conditions (WALTON, 1968, JAIN et.al., 1982, SIMMONDS, 1979, PAL, 1972). Breeding methods for improvement of allogamous crops should be based on the nature and magnitude of genetic variance (combining ability) controlling the inheritance of quantitative traits. Selection of crosses may be based on specific combining ability and *per se* performance linked with heterosis and inbreeding depression for cross exploitation. The present study is an attempt in this direction and undertaken to estimate the combining ability of the F_1 and F_2 populations, and the magnitude and direction of heterosis and inbreeding depression for yield and yield components in grain amaranth (*Amaranthus hypochondriacus* L.).

MATERIALS AND METHODS

The material for the present investigation comprised of six accessions of *A. hypochondriacus* namely, AG-16 (Calicut, Kerala), AG-26 (Mahabaleshwar, Maharastra), AG-19/2 (NBRI, Lucknow), AG-24 (Garhwal, Uttrakhand), AG-21 (Barabanki, U.P.) and AG-19/1 (NBRI selection) and their 15 cross combinations in F_1 and F_2 generations. These crosses, were developed using diallel-mating system. The experimental material was planted in randomized complete block design with three replications in rabi season at National Botanical Research Institute, Lucknow. The parents, check and F_1s were raised in single row and F_2s in two-row with 3m-row length, row-to-row and plant to plant distance 40cm and 15cm, respectively. Observations were recorded on 10 random plants from each plot in the parents and F_1s and on 30 plants in F_2 generation for 10 characters. Combining ability analysis was done according to Method 2, Model I of GRIFFING (1956). Heterosis over mid parent (MP) and better parent (BP) were calculated as F_1-MP/MPx100 and F_1-BP/BPx100. Inbreeding depression was worked out as F_1-F_2/F_1 x 100. T- test of inbreeding depression (ID) was calculated as estimated value of ID/standard error of mean.

RESULTS

The variance due to GCA was highly significant for almost all characters in both generations except test weight (1000 grains), similarly, the variance due to SCA was highly significant for almost all the characters in both F_1 and F_2 except for grain weight/panicle and harvest index in F_1 and F_2 and days to flowering in F_1 generation (Table 1), indicating that the parents and crosses differ significantly in their combining ability effects. The estimates of GCA (6^2gi) and SCA (6^2 sij) variances reflected the additive and non-additive genetic components are involved in determining the inheritance of these characters. The magnitude of of 6^2 sij was higher than 6^2 gi for almost all the characters in both generations. Hence, non-additive genetic variance is playing more important role in the inheritance of these traits. RUIZ et. al. (2004) and ORTIZ and GOLMIRZAIE (2004) have reported similar observations in potato. Although the additive gene action would imply some scope for selection in segregating generations, but presence of marked non-additive action suggests the population improvement followed by recurrent selection to accumulate desirable genes and facilitating for breaking of linkage through disruptive selection would be more appropriate.

The estimates of GCA effects (Table 2) revealed that AG-19/2 and AG-19/1 are the good general combiners for 6 out of 10 characters: for days to flowering, days to maturity, panicles/plant, panicle length, test weight and AG-16 and AG-26 for dwarfness in F_1 and F_2 and AG-21 for grain yield/plant in both generations, AG-24 for harvest index in F_1 and F_2 and AG-16 for protein content in both generations. The difference in genetic make up of two generations may be responsible for the difference in combining ability of different parents. It is clear from Table 2 that the parent AG-21, which is good general combiner for grain yield also showed high gca effects for panicles/plant and harvest index in F_1 and F_2 generations. Range of MP heterosis and BP heterosis designated as heterobeltiosis (FANSECO and PETERSON, 1968) and best hybrid on the basis of mean performance are presented in Table 3. The extent of inbreeding depression for various characters in F_2 is given in Table 4.

Five crosses flowered earlier than their respective early parents. The cross AG-19/2 x AG-24 was earliest among all. AG-26 x AG-19/2 is only hybrid, which is shorter than the others and exhibited higher heterosis over better parent for dwarfism. None of the F_2 progenies was earlier on pooled basis than their F_1 hybrids. Five F_2 progenies were shorter in plant height than the corresponding F_1 hybrid (Table 4). Heterosis over better parent was highest for grain yield/plant (145.047) followed by panicles/plant (113.675), panicle length (33.656) and grain weight/panicle (23.566).

For panicles/plant, eight hybrids showed significant positive heterosis over better parent. The cross AG-26xAG-19/1 was best for this character. For panicle length AG-26xAG-21 showed significant heterobeltiosis (33.656%) while four crosses showed significant MP heterosis (Table 3). The cross AG-26xAG-21 showed negative inbreeding depression for panicle length. The cross AG-26xAG-19/1 showed the maximum improvement for panicles/plant over better parent

(113.675%). One hybrid (AG-26 x AG-21) showed negative inbreeding depression (-6.636%) for panicles/plant. Six hybrids exhibited positive heterosis for seed weight/panicle. The inbreeding depression for this trait ranged from 0.00-23.565%.

Table 1. Anova (M.S.S.) for combining ability parameters) in F_1 and F_2 generations of grain amaranths

Character	Gca		Sca		Error		6^2gca		6^2 sca	
	F_1 (5)	F_2 (15)	F_1 (15)	F_2 (15)	F_1 (60)	F_2 (60)	F_1	F_2	F_1	F_2
Days to flowering	7.934	10.182**	7.113*	4.610	2.612	1.861	0.037	0.442	2.135	1.078
Days to maturity	285.380**	463.380**	231.986**	195.175**	2.134	2.564	-3.773	21.795	141.676	118.680
Plant height	574.300**	601.820**	279.550**	179.524**	9.461	14.702	23.706	32.946	161.875	96.565
Panicles/plant	440.064**	280.468**	175.810**	237.344**	40.875	29.164	21.326	3.006	68.144	111.860
Panicle length	6.734*	15.139**	5.883*	7.388**	1.886	1.320	0.045	0.617	1.872	2.951
Grain weight/panicle	0.996**	0.551	0.190	0.613	0.184	0.262	0.017	-0.007	-0.055	0.136
Test weight (1000 grains)	0.002	0.003*	0.000	0.002	0.001	0.001	0.000	0.000	0.000	0.000
Grain yield/plant	1428.520**	1107.020**	1306.573**	1282.026**	87.115	60.280	5.994	-18.543	721.965	735.158
Harvest index	26.920**	41.826**	84.103**	68.884**	5.190	2.975	-5.027	-2.466	47.684	39.686
Protein content	6.474*	1.518	4.836*	6.219*	1.526	1.485	0.116	-0.423	1.742	2.380

*, ** Significant at 5% and 1% levels, respectively.

Note : Degrees of freedom given in parentheses.

Tabela. 2 Ranking of desirable parents based on per se performance and GCA effect for 10 characters in grain amaranths

Character	Good parents based on per se performance	Good General combiners	
		F_1	F_2
Days to flowering	AG-26, AG-19/2, AG-19/1	AG-19/2, AG-24, AG-19/1	AG-26, AG-19/2, AG-24, AG-19/1
Days to maturity	AG-19/1, AG-19/2	AG-19/2, AG-19/1	AG-19/2, AG-19/1
Plant height	AG-16, AG-24	AG-16, AG-26, AG-24	AG-16,AG-26, AG-24
Panicles/Plant	AG-21, AG-19/2	AG-21, AG-19/1, AG-19/2	AG-21, AG-19/1
Panicles length	AG-26, AG-21	AG-21, AG-19/1	AG-19/1, AG-21
Grain weight/panicle	AG-24, AG-16	AG-16, AG-24	AG-24, AG-16
Test weight	AG-24, AG-19/2	AG-24, AG-19/2	AG-24, AG-19/2
Grain yield/plant	AG-21, AG-24	AG-21, AG-19/1	AG-21
Harvest index	AG-21, AG-19/2	AG-24	AG-21, AG-24
Protein content	AG-16, AG-21	AG-16	AG-16

Table 3. Range of heterosis and best hybrid for various quantitative characters in grain amaranths

Character	Range		Best hybrids based on mean performance
	MP heterosis	BP heterosis	
Days to flowering	-2.301– 10.555*	2.072 – 15.083*	AG-24 x AG-16 (P x A)
Days to maturity	-6.383– 8.709**	-3.777 – 63.486**	AG-19/2 x AG-24 (P x G)
Plant height	10.340– 38.986**	13.992* – 52.333**	AG-26 x AG19/2 (P x G)
Panicles/plant	-7.241– 145.367**	7.010 – 113.675**	AG-26 x AG-19/1 (P x A)
Panicle length	-0.368– 34.681**	-15.687 – 33.656**	AG-26 x AG-21 (P x G)
Grain weight/panicle	-0.581– 30.330*	0.000 – 23.566	AG-24 x AG-19/1 (H x A)
Test weight	-0.193– 8.239	-7.473 – 10.937	AG-19/2 x AG-24 (P x G)
Grain yield/plant	-4.330 – 153.643**	15.178 – 145.047**	AG-24 x AG-19/1 (P x G)
Harvest index	-2.466 – 32.086**	0.408 – 31.276**	AG-24 x AG-19/1 (G x P)
Protein content	-16.980 – 37.580**	-2.450 – 17.310**	AG-26 x AG-19/1 (P x P)

G – good, A – average, P – poor general combiner.

Table 4: Range of inbreeding depression (I.D.) and crosses showing lowest and highest I.D. for different characters in F_2 generation

Character	Range of I.D.	Crosses showing	
		Lowest I.D.	Highest I.D.
Days to flowering	-12.973* – 10.945	AG-26xAG-19/1, AG-26xAG-19/2	AG-24xAG-21, AG-21xAG-19/1
Days to maturity	-0.206 – 20.120*	AG-26xAG-21, AG-26xAG-24	AG-24xAG-19/1, AG-19/2xAG-21
Plant height	-0.776 – 22.013**	AG-21xAG-19/1, AG-26xAG-24	AG-26xAG-21, AG-19/2xAG-24
Panicles/plant	-6.636 – 37.448*	AG-16xAG-26, AG-24xAG-21	AG-26xAG-21, AG-19/2xAG-24
Panicle length	-1.062 – 28.502**	AG-19/2xAG-21, AG-26xAG-19/1	AG-26xAG-21, AG-26xAG-19/2
Grain weight/panicle	0.000 – 23.566	AG-16xAG-19/1, AG-16xAG-26	AG-19/2xAG-21
Test weight	-0.662 – 7.713	AG-19/2xAG-24	AG-16xAG-19/2
Grain yield/plant	-2.043 – 17.791*	AG-21xAG-26, AG-19/1xAG-26	AG-21xAG-19/2, AG-19/2xAG-16
Harvest index	-2.975 – 1.434	AG-26xAG-26, AG-19/1xAG-16	AG-19/1xAG-19/2
Protein content	-16.950 – 18.860*	AG-21xAG-26, AG-24xAG-26	AG-19/2xAG-26, AG-19/2xAG-16

In general, low heterotic values and inbreeding depression was observed for 1000 seed weight. The same observations were also recorded in black mustard (Schuster et.al. 1978), wheat (SINOLINDING and CHOWDRY, 1974) and barley (UPADHYAY and RASMUSSON, 1967).

For grain yield seven hybrids were significantly superior than both mid parent and better parent. The cross AG-24xAG-19/1 showed the best heterosis (Table 3). The inbreeding depression for grain yield ranged from –2.043 to 17.791 (Table 4). Ten hybrids over their better parent were observed significantly superior for harvest index. For protein content in F_2 generation five best F_2s for four characters out of 10, involved one parent with high gca effect and other with poor gca effect. Out of these four characters: plant height, test weight and grain weight/panicle also had the minimum or negative inbreeding depression, such F_2s may throw up desirable transgressive segregants. Such observations were also reported in rapeseed (RAI and VARSHNEY, 1983). For all the characters the best F_1 on the basis of mean performance, better heterosis and sca effect was same. Hence, equal importance shall be given to *per se* performance while making selection for these attributes.

In general, the hybrids, which showed high heterosis for grain yield also had high heterosis for plant height and protein content beside other yield contributing characters. Such a situation of 'combinational heterosis' was also reported in rapeseed (HAGBERG, 1952, DAS and RAI, 1972, VARSHNEY, 1985). A close relationship between heterosis response and inbreeding depression, i. e. hybrids which showed high heterosis linked with high inbreeding depression as well as the high magnitude of 6^2sij suggested the importance of non-additive gene action in inheritance of these characters in grain amaranths. Similar observations were reported in rapeseed (RAI and VARSHNEY, 1983), Phaseolus (SINGH and SINGH, 1970), mungbean (TIWARI et. al. 1993), lentil (GUPTA and SINGH, 1994) barley (BHATNAGAR and SHARMA, 1995), (HAYS and PARODA, 1974), (HAUNG, 1984), (EINFELDT et. al., 2005). The cross AG-19/2 x AG-19/1 had the highest yield in F_1 coupled with high harvest index and high positive heterosis for these traits with high sca effects both in F_1 and F_2 generations. Such crosses may be exploited for yield improvement in this crop.

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REFERENCES

BHATNAGAR, V. K and S.N. SHARMA (1995): Diallel analysis for combining ability for grain yield and its components in barley. Ind. J. Genet.,*55*: 228-232.

BERGHOFER, E. and SCHOENLECHNER (2002): Grain amaranth in pseudocereals and less common cereals. Ed. by Belton, P.S. Taylor, JRN, Springer-Verlag, Berlin pp. 219-260.

DAS, B. and RAI, B. (1972). Heterosis in intervarietal cross of toria. Ind. J. Genet., *32*: 197-202.

EINFELDT, C.H.P., S. CECCARELLI, S. GRANDO, A GLAND-ZWERGER and H.H.GEIGER (2005): Heterosis and mixing effects in barley and drought stress. Plant Breeding, *124* : 350-355.

FANSECO, S. and F.L.PETERSON (1968): Hybrid vigor in seven parent diallel cross in common wheat (*T. aestivum* L.). Crop Sci., *8*: 85-88.

GRIFFING, B. (1956). Concept of general and specific combining ability in relation to diallel crossing system. Aus:ralian J. Biol. S*ci.*, *9* : 463-493.

GUPTA, M.P. and I.P. SINGH, (1994): Combining ability in lentil. *Astr. Intern. Symp.* on Pulses Research 2-6 April, 1994, New Delhi : 107-108.

HAYS, J.D. and P R.S.ARODA, (1974): Parental generation in relation to combining ability analysis in spring barley. Theor. Appl. Genet., *44* : 373-377.

HAUNG, Z.R. (1984): Studies on heterosis and combining ability in F_1 hybrid of six rowed barley. Acta Agron. Sinica*, 10* : 123-131.

HAGBERG, A. (1952): Heterosis in F_1 combination in Galoopris I and II. Hereditas *38* : 321-325.

JAIN, S.K., H.HAUPTLI, and K. VAIDYA, (1982): Out-crossing rates in grain amaranths. Jour. Herd., *73*: 71-72.

ORTIZ, R. and GOLMIRZAIE, (2004): Combining ability analysis and correlation between breeding values in true potato seed. Plant Breeding, *123* : 546-567.

PAL, M. (1972): Evolution and improvement of cultivated amaranths I. Breeding system and inflorescence structure. Proc. Ind. Natl. Sci. Acad., *38:* 28-37.

RAI, B. and S.K.VARSHNEY, (1983): Genetic basis of breeding better varieties of Indian rapeseed. Abstr. XV Intern. Congr. Genet. Dec. 12-21, 1983. New Delhi No. 1065: 593.

RUIZ DE GALARRETA, J. I., B. EZPELETA, J.. PASCUALENA and R E.ITTER (2006): Combining ability and correlation for yield components in early generations of potato breeding. Plant Breeding. *125* **:** 183-186.

SAUER, J.D. (1967): The grain amaranths and their relatives: A revised taxonomic and geographic survey. Ann. Misorr. Bot. Gard. *54***:** 103-137.

SCHUSTER, I.D. A. ALAWI, and R.C.EI-SEIDY (1978): Studies on breeding and heterosis phenomenon in black mustard (*Brassica nigra* L.). Bot., *52* **:** 215-232.

Simmonds, N.W. (1979). Principles of crop improvement. Longman London.

SINGH, T.P. and K.B. SINGH (1970): Mode of gene action for yield and its components in *Phaseolus aureus,* Roxb. I.Canad. J. Genet. Cytol., *14* **:** 517-525.

SINOLINDING, K.P. and C A.R.HOWDRY, (1974): Heterosis and combining ability in wheat under irrigation and moisture stress. Expl. Agric. *10* **:** 241-245.

TIWARI, D.S., V. SINGH, and S P.S.HUKLA (1993): Combining ability studies in mungbean (*Vigna radiata* L.) *Wilezek* Indian. J. Genet., *53* **:** 395-398.

Upadhyay, B.R. and D.C.RASMUSSON (1967):. Heterosis and combining ability in barley. Crop. Sci., *7* **:** 644-647.

VARSHNEY, S.K. (1985). Heterosis in crosses between parents selected for harvest index and plant height in Indian rapeseed. Indian J. Agric. Sci., *55* **:** 398-402.

WALTON, P.D. (1968). The use of *Amaranthus caudatus* in stimulating the breeding behaviour of commercial *Gossypium species*. Jour. Hered., ***59*** **:** 117-118.

PRIRODA I MAGNITUDA GENETIČKOG VARIJABILITETA, HETEROZISA I INBRIDING DEPRESIJE U AMARANTUSU

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I z v o d

Kombinaciona sposobnost, heterozis i inbriding depresija su određeni za deset svojstava u zrnu amarantusa. Neaditivna genetička varijansa je dominatna za većinu svojstava u F_1 i F_2 generaciji. Roditeljski genotip AG-21 je dobar generalni kombinator za prinos/biljka, takođe ima visok GCA efekat za metlica/biljka i žetveni indeks u F_1 i F_2 generaciji. Za sedam svojstava, najbolji F_2s na osnovu SCA sadrži jednog roditelja sa visokim i drugog sa niskim ili prosečnim GCA efektom. Hibridi koji pokazuju visok heterozis takođe pokazuje visoku inbriding depresiju. Heterosis u odnosu na boljeg roditelja je viši za prinos, zatim metlica/biljka (113.675%), dužina metlice(33.656%) i težinu zrna /metlica(23.566%).

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