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Character Association and Path Coefficient Analysis in Grain Amaranth (*Amaranthus* spp.)

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Abstract

Twenty-two genotypes of amaranth (*Amaranthus spp.*) were evaluated for 12 quantitative traits for two years and the pooled data was analyzed. The mean, range, genotypic and phenotypic coefficient of variation, heritability in broad sense and genetic advance were calculated. Path coefficient analysis was carried out using correlation coefficients to know the yield-contributing traits having true associations with seed yield. The low differences between the phenotypic and genotypic coefficients of variations indicated low environmental influences on the expression of the traits studied. High heritability coupled with high genetic advance for yield/day to maturity, yield/day to seed fill, harvest index, panicle girth and seed yield/plant was observed. All the traits except days to seed fill possessed positive association with grain yield. Harvest index was positively correlated with days to maturity. Harvest index, aerial biomass/plant and days to maturity also had high phenotypic and genotypic direct effects on seed yield/plant, revealing that indirect selection for these traits would be effective in improving seed yield.

Highlights

- The characters yield/day to maturity, yield/day to seed fill, harvest index, panicle girth and seed yield/plant showed high heritability coupled with high genetic advance
- The path coefficient analysis revealed harvest index, panicle girth, aerial biomass/plant and days to maturity as the most important yield component traits that should be taken into account while formulating selection strategies in amaranth.

Keywords: amaranth, correlation, heritability, path analysis, variability

Introduction

Amaranth (*Amaranthus spp.*) is an annual herbaceous crop with C_4 type photosynthesis and is one of the valuable foods as it has high protein content and balanced amino acid profile (Gamel *et al.*, 2006). It is a traditional crop of Himalayan region generally cultivated as mixed crop as well as sole. With the increasing need of exploring alternate sources of food, it is necessary to accelerate and expand the production of amaranth. Recently, importance attributed to this crop due to its inherent high nutritional quality and adaptation to unfavorable and water scarce conditions along with sustainability of production and diversification of agriculture, haunts the breeders to make efforts for the varietal improvement through enhanced plant breeding activity. Of the several plant breeding endeavors which have been in vogue for the improvement of crops, exploration of natural variability and use of selection *per se* or by computing a selection index is one of the most simple *ab initio* of the modern methods. This method is specifically suitable for the crops like amaranth, where considerable natural genetic variability is present specifically in the Himalayan region because of its geo, agro and bio-diversity.

Since yield is a complex trait having low heritability, *per se*, selection is generally ambiguous and leads to unpredictable results. Indirect selection by making use of highly heritable, simple inherited traits have been advocated and used for the improvement of yield since time immemorial. Borojevic (1990) and Wallace *et al.* (1993) proposed that efficiency of breeding for higher yield can be raised by applying yield system analysis. They identified the three major genetically controlled, physiological components of yield and gave a group of eight sub-component traits of yield and the group of these nine traits including yield were christened yield system traits, to be studied for making their use in indirect selection for yield. Hence, to identify most suitable traits, leading to gains in yield by indirect selection in the present study, considerations of taking observations on yield system traits, some basic yield subcomponent traits and traits associated with yield have been made.

Materials and Methods

Plant material and experimental layout

The material for present study consisted of twenty-two amaranth genotypes *viz*, Annapurna, IC35407, JRS502, JRS503, JRS504, JRS505, JRS506, JRS507, JRS508, PRA9101, Sangla A1, Sangla A2, Sangla A3, Sangla A4, Sangla A5, Sangla A6, Sangla A7, Sangla A8, Sangla A9, Sangla A10, Sangla A11 and Shimla A1. The experimental material was planted in two growing season (Kharif 2002 and 2003) in a Randomized Complete Block Design with three replications at the experimental farms of CSKHPKV, Palampur. The plot size was kept as 1.5m x 3.15m. Each entry was raised in three rows and the rows were 50 cm apart and plant to plant distance was 15 cm, which was maintained by thinning.

Recording of data

The data were recorded on nine yield system traits (Wallace *et al*., 1993) *viz*., days to flowering, days to maturity, days to seed fill, aerial biomass per plant at harvest maturity, seed yield per plant at harvest maturity, yield per day to maturity, yield per day to seed fill, biomass per day to plant growth and harvest index. Other traits recorded were plant height, panicle length and panicle girth.

Data on different traits was taken on five random plants in each replication, except on days to flowering, days to maturity and days to seed fill where it was recorded on plot basis. All the recommended package of practices was followed to raise a good crop.

Data analysis

Analysis of variance was performed following linear model given by Fisher (1954) and Panse and Sukhatme (1984). The phenotypic and genotypic coefficients of variation (PCV, GCV), heritability in broad sense and expected genetic advance were calculated as suggested by Burton and Devane (1953). The genotypic and phenotypic coefficients of correlation were computed as per AI Jibouri *et al.* (1958). Path coefficient analysis was worked out following Dewey and Lu (1959). In the present investigation, path coefficient analysis was carried out by taking seed yield/plant as dependent variable and other observed traits as independent variables.

Results and Discussion

Analysis of variance revealed significant differences for individual as well as pooled data amongst genotypes for all the twelve traits studied indicating the presence of sufficient variability for making effective selection. Variance due to genotype was highly significant for all the traits indicating the presence of sufficient variability in the genotypes used in the present study. The high magnitude of variability may be due to the fact that the genotypes are collected from the different locations (Table 1). High magnitude of variability has been reported in amaranthus for various characters by many workers; for days to flowering, days to maturity, plant height, panicle length (Sharma *et al*., 2003).

Phenotypic coefficient of variation was slightly higher than genotypic coefficient of variation for all the observed characters indicating that there is little environmental influence on the genotypic expression of the traits (Table 1). Of the nine yield system traits high PCV and GCV was observed for yield/day to maturity, yield/day to seed fill, harvest index and seed yield/plant. Yield/day to seed fill and yield/day to maturity are the two most important traits for yield enhancement along with harvest index which is the actual partitioning of photosynthate from total biomass

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to economic yield ((Wallace *et al*., 1993). These traits have been reported as main yield contributing traits (Watson, 1952). Similar findings pertaining to the presence of high genetic variability were reported for different traits including seed yield/plant (Joshi and Rana, 1955). Result revealed the presence of high genetic variability in the test genotypes for the major yield contributing characters along with seed yield which indicated that further improvement for these traits is possible.

Although GCV is an indicator of the presence of high degree of genetic variation but the amount of heritable variation can only be determined with the heritability estimates and genetic gain (Naik, 2012). Heritability estimates is an informative parameter to the breeder for selecting the varieties for further use. The estimates of heritability were higher for all the traits except plant height indicating major role of genotypes in expression of these characters (Table 1). High heritability for different traits *viz.*, days to flowering, days to maturity, panicle length and seed yield (Joshi, 1986) has also been reported earlier. Genetic advance as percent of mean was higher for yield/day to maturity, yield/day to seed fill, harvest index, panicle girth and seed yield/plant indicating that selection for these traits would be effective for the improvement. Similar findings related to high genetic advance as percent of mean have been reported by earlier workers for various traits (Ghosh *et al.*, 1999). Heritable variation can be found out with greater degree of accuracy when heritability is studied in conjunction with genetic advance. The traits showing high genetic advance also showed high heritability in the present study.

Table 1: Estimation of different genetic parameters of variation over two seasons (pooled data)

Traits	Mean	Range	PCV	GCV	Heritability (%)	Genetic advance (%)
Days to flowering	77.26	69.00-82.67	5.73	5.51	92.30	10.90
Days to maturity	137.85	129.33-145.33	3.41	3.24	90.30	6.34
Days to seed fill	60.59	52.67-73.00	7.89	7.26	84.60	13.75
Aerial biomass/plant (g)	68.69	63.32-75.75	6.49	6.30	94.20	12.61
Yield/day to maturity (g)	0.07	0.06-0.10	18.50	17.04	84.80	28.57
Yield/day to seed fill (g)	0.17	0.13-0.24	19.85	18.96	91.20	35.29
Biomass/day to plant growth(g)	0.50	0.45-0.54	4.85	4.56	88.60	8.02
Harvest index (%)	14.92	12.60-19.68	13.87	13.19	90.50	25.87
Plant height (cm)	172.82	154.10-200.35	10.45	7.35	49.50	10.65
Panicle length (cm)	59.10	56.39-65.27	4.68	3.44	54.10	5.21
Panicle girth (cm)	20.71	17.97-26.37	13.82	13.66	97.70	27.81
Seed yield/plant (g)	10.32	8.15-14.91	19.99	19.60	96.10	39.53

Table 2: Phenotypic correlations among different pair of traits in amaranth (pooled data)

Traits	Days to maturity	Days to seed fill (g)	Aerial biomass/ plant (g)	Yield day to maturity (g)	Yield/ day to seed fill (g)	Biomass/ day to plant growth (g)	Harvest index (%)	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	Yield/ plant (g)
Days to flowering	0.453*	-0.480*	0.402	0.418	0.587*	0.231	0.404	0.269	0.443*	0.487*	0.426*
Days to maturity		0.564*	0.687*	0.428*	0.366	0.248	0.511*	0.398	0.365	0.597*	0.581*
Days to seed fill			0.304	0.034	-0.184	0.030	0.129	0.142	-0.051	0.135	0.177
Aerial biomass/ plant (g)				0.848*	0.790*	0.868*	0.826*	0.668*	0.585*	0.890*	0.911*
Yield/day to maturity (g)					0.947*	0.844*	0.959*	0.672*	0.541*	0.898*	0.960*
Yield/day to seed fill (g)						0.806*	0.933*	0.629*	0.568*	0.897*	0.928*
Biomass/day to plant growth (g)							0.760*	0.637*	0.542*	0.776*	0.823*
Harvest index (%)								0.638*	0.498*	0.926*	0.984*
Plant height (cm)									0.626*	0.634*	0.667*
Panicle length (cm)										0.596*	0.545*
Panicle girth (cm)											0.954*

* Significant at 0.05 level

Table 3: Estimate of direct and indirect phenotypic and genotypic effects of different traits on yield in amaranth (pooled data)

Traits		Daysto flowering	Daysto maturity	Daysto seed fill	Aerial biomass/ plant (g)	Yield/ dayto maturity (g)	Yield/day to seed fill (g)	Biomass/ day to plant growth (g)	Harvest index (%)	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	Correl- ation
Days to flowering	P	-0.509	0.237	0.263	0.132	-0.013	0.019	-0.004	0.285	-0.001	-0.001	0.019	0.426*
	G	0.023	0.030	0.005	0.059	-0.058	-0.021	0.039	0.354	-0.003	-0.003	0.017	0.439
Days to maturity	P	-0.231	0.522	-0.309	0.225	-0.013	0.012	-0.005	0.361	-0.001	0.000	0.023	0.581*
	G	-0.011	0.061	-0.005	0.097	-0.071	-0.016	0.048	0.495	-0.005	-0.002	0.021	0.632
Days to seed fill	P	0.245	0.295	-0.548	0.100	-0.001	-0.006	-0.001	0.091	-0.001	0.000	0.005	0.177
	G	-0.011	0.033	-0.010	0.042	-0.016	0.004	0.011	0.160	-0.002	0.001	0.005	0.218
Aerial biomass/ plant (g)	P	-0.205	0.359	-0.166	0.328	-0.026	0.025	-0.016	0.583	-0.002	-0.001	0.034	0.911*
	G	0.010	0.044	-0.003	0.134	-0.124	-0.030	0.131	0.778	-0.008	-0.003	0.031	0.956
Yield/day to maturity(g)	P	-0.213	0.223	-0.019	0.278	-0.030	0.031	-0.015	0.677	-0.002	-0.001	0.035	0.960*
	G	0.010	0.033	-0.001	0.126	-0.131	-0.034	0.136	0.833	-0.007	-0.003	0.033	0.994
Yield/day to seed fill (g)	P	-0.299	0.191	0.101	0.259	-0.029	0.032	-0.015	0.658	-0.002	-0.001	0.035	0.928*
	G	0.014	0.028	0.001	0.115	-0.128	-0.035	0.129	0.800	-0.007	-0.003	0.032	0.944
Biomass/day to plant growth (g)	P	-0.117	0.129	-0.016	0.285	-0.025	0.026	-0.018	0.536	-0.002	-0.001	0.030	0.823*
	G	0.006	0.020	-0.001	0.118	-0.121	-0.031	0.148	0.722	-0.008	-0.003	0.028	0.876
Harvest index (%)	P	-0.206	0.267	-0.071	0.271	-0.029	0.030	-0.014	0.706	-0.002	-0.001	0.036	0.984*
	G	0.010	0.036	-0.002	0.123	-0.130	-0.034	0.127	0.843	-0.007	-0.003	0.033	0.995
Plant height (cm)	P	-0.137	0.208	-0.008	-0.219	-0.020	0.020	0.099	0.719	-0.004	-0.001	0.024	0.667*
	G	0.009	0.037	-0.002	0.135	-0.126	-0.031	0.148	0.731	-0.008	-0.003	0.032	0.920
Panicle length (cm)	P	-0.226	0.191	0.028	0.192	-0.016	0.018	-0.010	0.352	-0.002	-0.001	0.023	0.545*
	G	0.015	0.031	0.001	0.099	-0.102	-0.028	0.099	0.593	-0.007	-0.004	0.027	0.723
Panicle girth (cm)	P	0.248	-0.312	-0.074	0.292	-0.027	0.029	0.134	0.653	-0.002	-0.001	0.038	0.954*
	G	0.012	0.031	-0.001	0.123	-0.128	-0.034	0.124	0.824	-0.007	-0.003	0.034	0.979

* Significant at 0.05 level Residual effect (P = 0.0011, G = -0.0015)

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The correlation coefficients estimated between seed yield and other traits under study indicated that seed yield was positively correlated with all the yield system traits except days to seed fill which shows non-significant association with yield and biomass but genotypic correlation was quite high (Table 2). Similar results were reported by Berssani *et al*. (1987). Hence, selection for these traits would also help in improving the seed yield in this crop.

Path analysis helps in partitioning the genotypic correlations into direct and indirect effects of component characters in yield. Results of path coefficient indicated that panicle girth, harvest index, aerial biomass/plant and days to maturity exhibited positive phenotypic and genotypic direct effects on seed yield/plant (Table 3). Phenotypic direct effect of yield/day to seed fill on seed yield/plant was positive, however, its genotypic direct effect was negative. It is evident that the positive correlation between seed yield/ plant and yield/day to seed fill was mainly due to harvest index. The phenotypic direct effect of panicle girth is positive but low, therefore, direct selection for this trait may not help in yield improvement. Alternatively, harvest index, aerial biomass/plant and days to maturity had higher phenotypic and genotypic direct effects on seed yield/plant, thus, the correlation coefficient between seed yield and these three traits is real one, revealing that indirect selection for these traits would be effective in improving seed yield. Harvest index also showed high heritability along with high genetic advance thus, indirect selection for this trait would be most effective for the improvement of seed yield. These findings are in accordance with the earlier reports (Agong and Ayiecho, 1992, Bressani *et al*., 1987) where direct positive effect of harvest index to seed yield/plant has been reported in amaranth. Other researchers have also considered higher rate of biomass accumulation to be the only option for higher yield in oats (Robertson and Frey, 1987).

Conclusion

The research evaluated twenty-two grain amaranth genotypes for two years and revealed the presence of high genetic variability in the test genotypes for the major yield contributing characters along with seed yield which indicated that further improvement for these traits is possible. High PCV and GCV was observed for yield/day to maturity, yield/day to seed fill, harvest index and seed yield/plant. These traits are the most important traits for yield enhancement. Harvest index, aerial biomass/plant and days to maturity had higher phenotypic and genotypic direct effects on seed yield/plant, revealing that indirect selection for these traits would be effective in improving seed yield. Thus, the material studied is of diverse nature and information emanated would help in designing the selection methodology which can further be used in the breeding programme for improvement of yield in amaranth through indirect selection for the identified traits.

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