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STUDIES ON STABILITY, CORRELATION AND PATH CO-EFFICIENT ANALYSIS FOR GRAIN YIELD AND COMPONENT TRAITS IN AMARANTH

S. Ramesh Kumar[1] and G. Mohamed Yassin[2]

[1]Department of Horticulture, Vanavarayar Institute of Agriculture, Manakkadavu, Pollachi-642 103, Tamil Nadu Agricultural University, Tamil Nadu, India
[2]Department of Horticulture, Pandit Jawaharlal Nehru College of Agriculture and Research Institute, TNAU, Karaikal-609603, Puduchery, India

ABSTRACT: *Amaranthus hypochondriacus L. is mono-cropped at different plant spacings. Genotype performance varies widely over densities due to variety genetics. It is necessary to identify stable genotypes. Information on genotypes and density will allow for a better evaluation of variety stability. Amaranth genotypes were evaluated for yield characters under very high (D_1), high (D_2), normal (D_3) and low (D_4) plant densities to identify stability parameters. The study was conducted at Karaikal, India, during November-February 2007-2008. Genotype Annapurna was stable for grain yield in all plant densities. Genotypes BGA 2, GA 2 and IC 415290 were stable for total carbohydrates and protein content and could be utilized for improvement of these traits. Genotype GA 2 was stable for weight of the inflorescence in all plant densities. Similarly, SKNA 601 was stable for leaf area at 50% flowering in all plant densities. Among characters studied, length of the rachis per inflorescence, total carbohydrates and protein content were relatively stable in all plant densities. These traits are important for selection for improvement at different densities. Results of correlation analysis indicated that weight of the inflorescence, length of the primary inflorescence and number of secondary branches per inflorescence were positively correlated with grain yield and among themselves, indicating that improvement of grain yield in amaranthus could be achieved by selection for these component traits. Path analysis indicated that weight of the inflorescence, leaf area at 50% flowering, length of the primary inflorescence and number of secondary branches per inflorescence had direct positive effects on grain yield. Therefore, the abovesaid traits are important while exercising selection for different density levels.*

KEYWORDS: Amaranthus hypochondriacus, selection, stability parameters

INTRODUCTION

Grain amaranth (*Amaranthus hypochondriacus* L.) production has declined mainly due to lack of producer awareness of its nutritive value, non-availability of suitable high yielding varieties and lack of improved production techniques. Varietal improvement is needed to increase yield potential of this crop. Proper plant densities is essential in maximizing grain yield (Henderson et al., 1993). Exploitation of heterosis and success in obtaining desirable segregants through breeding depends to a greater extent on degree of genetic divergence between parents (Priya, 2007). Grain amaranthus genotypes capable of stable yield under different population densities are lacking. Genotypic correlations between grain yield and yield attributing characters are important in breeding programs. Since yield is the end product of many correlated characters, selection for yield would be more effective based on component characters which are positively correlated. When more variables are considered in correlation, the association increases in

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complexity. A better insight into the cause of association is provided by path coefficient analysis, a method of partitioning correlation coefficients into direct and indirect effects of component characters. Correlation of various characters with yield is useful and provides criteria for direct selection of component characters (Goulden, 1952). Improvement of yield contributing traits, which can be better ascertained if the nature and kind of association of such traits with yield is available, must be considered. Partitioning of total correlation into direct and indirect effects by path analysis helps in making selection more effective. Path coefficient analysis studies are used to separate correlation coefficients into components of direct and indirect effects toward yield.

Materials and Methods

Grain amaranthus genotypes were obtained from the germplasm collection of NBPGR maintained at the University of Agricultural Sciences, Bangalore and Forestry College and Research Institute, Mettupalayam, India (Table 1). Plants were grown from November-February, 2007 in a Randomized Complete Block Design with three replications. The soil was a well drained sandy loam, pH above 6. The soil was prepared by cultivation three times to obtain a loose, friable, soil. Cow manure was applied along with urea, diammonium phosphate and muriate of potash as per TNAU crop production guide (2005). Irrigations were at a 7 day interval during the growing season. The insecticides chloriphyriphos or dimethoate were applieded at 1.5 $mL \cdot L^{-1}$. Genotypes were grown in bed of 2 × 1.5 m. Seed were sown in a single line in the middle of the bed. Plants were thinned 15 days after sowing to maintain very high (30 × 20 cm), high (30 × 30 cm), normal (45 × 20 cm) and low (45 × 30 cm) densities. Observations were recorded from five randomly selected plants of each genotype in each replication and population density for plant height, leaf area at 50% flowering, weight of the inflorescence, number of rachis per inflorescence, rachis length per inflorescence, number of secondary branches per inflorescence, grain yield per plant, grain yield per plot, and total carbohydrate and protein contents. For quality traits, composite samples drawn from five random plants of genotypes under population densities were used for analysis.

Stability analysis

The method of Eberhart and Russell (1966) was followed to estimate the parameters of stability: mean (x), regression coefficient (b) and mean square deviation (S^2d) for each genotype. In addition, the density index (I_j) and phenotypic index (Pi) were also estimated from mean data averaged over replications in the densities.

Correlation analysis

Associations between yield and component traits and correlations among component traits was computed based on average performance of genotypes as genotypic correlation coefficient (Goulden, 1952). Variance and covariance components were used to calculate genotypic correlation coefficients following Al-Jibour et al. (1958).

Path analysis

Path analysis of traits was done following Dewey and Lu (1959). Residual effect was variation in the dependent variable assumed to be due to variable(s) not included. Genotypic and phenotypic correlation coefficients were utilized to compute direct and indirect contribution toward net head weight. Direct and indirect paths were obtained following Dewey and Lu (1959).

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RESULTS AND DISCUSSION

Stability analysis

A stable genotype has low genotype (G) × density (D) interaction for agronomically important characters. Assessment of the G × D interaction is necessary to identify phenotypically stable genotypes. Regression analysis of the G × D interaction is used to characterize genotypic responses to densities (Sharma et al., 1998). Eberhart and Russell (1966) extended this approach and included deviation from the regression as an additional parameter, an approach widely used by breeders to detect high yielding stable genotypes.

Mean squares due to G × D was significant for most characters, indicating differences between densities and their influence on genotypes for expression of these characters. Sharma et al. (2001), Varalakshmi and Pratap Reddy (2002), Varalakshmi (2003), Sudhir Shukla and Singh (2003) and Kishore et al. (2007) observed significant differences for densities as well as for G × D interaction for yield and its component traits in grain amaranthus. In the present investigation, pooled analysis of variance indicated (Table 5) that plant density and the G × D interaction were significant for plant height, leaf area at 50% flowering, weight of the inflorescence, number of rachis per inflorescence, rachis length per inflorescence, grain yield per plant, and grain yield per plot (Table 3, 4). The G × D interaction effect was further partitioned into linear (predictable) and non-linear (unpredictable) components through analysis of variance for stability. The D + (G × D) interaction was significant for all characters, except total carbohydrates and protein content.

Differential effects of density on genotypes were significant for all characters, except plant height, leaf area at 50% flowering, weight of the inflorescence, number of rachis per inflorescence, rachis length per inflorescence, grain yield per plant, and grain yield per plot, as indicated by density (linear) mean squares. The linear component of G × D interaction was significant for plant height, leaf area at 50% flowering, weight of the inflorescence, number of secondary branches per inflorescence, number of rachis per inflorescence, length of the rachis per inflorescence, grain yield per plant and grain yield per plot, indicating predictions about performance of most genotypes appeared feasible for these characters. The significant mean squares due to pooled deviation observed for plant height, leaf area at 50% flowering, weight of the inflorescence, number of rachis per inflorescence, rachis length per inflorescence, grain yield per plant, and grain yield per plot indicated that genotypes differed with respect to their stability, representing the unpredictable component of G × D interaction.

Density indices computed for characters indicated that the normal density favored expression of all characters in the desirable direction except days to 50% flowering and total carbohydrates. The protein content was favorable at all plant densities except the very high density level. The length of the primary inflorescence, weight of the inflorescence, number of rachis per inflorescence, grain yield per plant, grain yield per plot and protein content were favorable under normal and high plant densities (Table 6 to 9).

Eberhart and Russell (1966) used the stability parameters (i) genotypic mean (g_i), expressed as phenotypic index (Pi), (ii) regression value (b) (predictable linear response) and deviation from linearity (S^2d) (unpredictable non-linear response) for identifying genotypes for all the plant densities. According to this model an ideal stable genotype is one which conforms to the following stability parameters: (i) phenotypic index is more than zero, represented by high genotypic mean (Pi > 0 i.e., $g_i > x$), (ii) regression coefficient is equal to unity (b =1) and (iii)

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deviation from regression is equal to zero ($S^2d = 0$). Such a genotype would be suitable for general adaptation over all densities.

A score chart was prepared for all genotypes and characters. The scores: 'm' for significantly higher (desirable) mean, i.e., Pi is more than zero; 'r' for 'b' value not significantly deviating from unity (i.e., b = 1) and'd' for S^2d value not significantly deviating from zero, $S^2d = 0$, were used. A combined score chart was computed for all genotypes for all characters (Table 10). The combined score chart indicated that 'Annapurna' and 'GA 2' were stable genotypes. The only other genotype which was acceptable for the three parameters for grain yield per plot was 'SKNA 601'. 'Annapurna' was also identified as the best genotype for plant densities based on its mean performance. Responses of 'Annapurna' to density is well known (Sharma et al.; 1998, 2001; Kishore et al., 2007) and is used to compare the fitness of other genotypes.

Genotype GA 2 was not stable for grain yield even though it had stable performance on weight of the inflorescence and number of rachis per inflorescence. It was also unstable across plant densities. Length of rachis per inflorescence was stable performance in genotypes RMA 3, Annapurna, SKNA 601, GA 2, RMA 4, I C 415290, and PRA 2004 - 2 .Total carbohydrates was stable in BGA 2, E C 519554, GA 2, I C 415290 and protein content was stable in BGA 2, Annapurna, GA 2, I C 415290. Grain yield per plant and per plot yield were stable in 'Annapurna' and 'Annapurna' and 'SKNA 601', respectively.

Details of genotypes showing stability for different traits were determined (Table 11). Genotype Annapurna was stable for grain yield per plot, grain yield per plant, plant height, length of the rachis per inflorescence and protein content. No other genotype was stable for grain yield per plot except 'SKNA 601'. For total carbohydrates and protein content, genotypes BGA 2, GA 2 and IC 415290 could be exploited based on their stability.

Stable performance occurred in genotypes RMA 3, Annapurna, SKNA 601, GA 2, RMA 4, IC 415290 and PRA 2004-2, for length of the rachis per inflorescence. This trait is an important yield contributing character at all plant densities except the very high density. These genotypes may be used to realize stable yield. The genotype SKNA 21 was stable for leaf area at 50% flowering which may be used for improvement of yield.

Correlation studies

Genotypic correlation coefficients indicated that grain yield per plant was positively and significantly relationed to weight of the inflorescence in all plant densities, except the high density. Length of the primary inflorescence and plant height was positively correlated with grain yield under very high and normal plant densities, respectively (Tables 12-15). Weight of the inflorescence was positively correlated with grain yield at the high plant density. Length of the inflorescence and plant height were positively correlated with grain yield at the very high and normal plant density levels, respectively.

Weight of the inflorescence, length of the inflorescence and number of secondary branches per inflorescence positively, and significantly, correlatied in all densities, except the low plant density. Plant height was positively correlated with diameter of the inflorescence, weight of the inflorescence and length of the primary inflorescence under very high, high and normal plant densities. This indicates that selection for any one of these may lead to improvement of individual characters concerned, but to simultaneous improvement of other traits. Days to 50% flowering were not correlated with grain yield in all plant densities. No significant negative

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correlations were observed for any trait with grain yield in all plant densities. To improve grain yield selection should be done using weight of the inflorescence, length of the primary inflorescence, number of secondary branches per inflorescence and leaf area at 50% flowering for improvement of grain yield in grain amaranthus in all plant densities.

Path analysis

Path analysis indicated that direct effects of all the component traits on grain yield exhibited high fluctuation in direction and magnitude under all plant densities. Among the traits: weight of the inflorescence, length of the primary inflorescence and number of secondary branches per inflorescence, which were identified as yield attributing traits based on correlation and intercorrelation studies, weight of the inflorescence was the most important contributing trait since grain yield per plant was improved in plant densities. In path analysis, as in correlation analysis, this trait had very high positive direct effects on grain yield in all plant densities. In addition leaf area at 50% flowering, length of the primary inflorescence and number of secondary branches per inflorescence were also important yield contributing traits from the path analysis in all plant densities. The length of the rachis per inflorescence had a high positive direct effect on grain yield per plant in all densities except the very high density.

Weight of the inflorescence should be important in selection for improvement of grain yield in grain amaranthus irrespective of plant density. A positive direct effect was exhibited by plant height in high and normal plant densities; in very high and low plant densities this trait had substantial negative direct effects. The yield contributing trait diameter of the inflorescence had a direct positive effect on grain yield in all densities except the high density. Total carbohydrates and protein content had high positive direct effects on grain yield in the very high density and also protein content had a low positive direct effect in the low plant density.

Days to 50% flowering and number of rachis per inflorescence had negative direct effects in all densities. Total carbohydrates had high, and negligible, negative direct effects on grain yield in normal, high and low plant densities, respectively. Protein content had a high negative direct effect at the normal density; in the high plant density this trait had negligible negative direct effects on grain yield. The estimate of residual effect reflects the adequacy and appropriateness of characters chosen for path analysis. The residual effect was low in all plant densities indicating the adequacy of characters chosen for the study to reflect the grain yield. Previous studies used correlation method, fewer densities and different varieties. The combination of these methods, and inclusion of previously untested varieties, provided more precise determinations of factors related to yield.

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ISSN 2053-5805(Print), ISSN 2053-5813(Online)

APPENDIX

Table 1. Genotypes source and availability; National Bureau of Plant Genetic Resources.

Genotype	Source	Status
RMA 3	Rajasthan	Released variety
BGA 2	NBPGR	Released variety
E C 519554	NBPGR	Breeding line
SKNA 21	Gujarat	Released variety
Annapurna	New Delhi	Released variety
SKNA 601	Gujarat	Released variety
GA 2	Gujarat	Released variety
RMA 4	Rajasthan	Released variety
I C 415290	NBPGR	Breeding line
PRA 2004 - 2	NBPGR	Breeding line

Table 2. Plant densities.

Character	Density			
	D_1 (very high)	D_2 (high)	D_3 (normal)	D_4 (low)
Spacing	30 × 20 cm	30 × 30 cm	45 × 20 cm	45 × 30 cm
Plant population/m^2	50	33	30	22
Plant population·ha^{-1}	500,000	333,000	330,000	2,22,222

Table 3. Values of environmental indices for different traits.

Character	Density[a]			
	Very high	High	Normal	Low
Plant height (cm)	4.64	-4.06	4.35	-4.95
Leaf area at 50% flowering (cm^2)	-10.69	-1.67	27.92	-15.57
Fresh weight of the inflorescence (g)	-3.66	2.55	4.77	-3.82
Number of rachis per inflorescence	-1.80	0.31	2.28	-0.78
Length of the rachis per inflorescence (cm)	-2.15	-0.85	1.93	1.10
Number of secondary branches per inflorescence	-0.28	-0.24	0.47	0.07
Grain yield per plant (g)	0.21	0.90	2.04	0.87
Grain yield per plot (g)	-8.16	107.90	48.68	-148
Total carbohydrate content (g/100g)	0.39	0.34	-0.23	-0.50
Protein content (g/100g)	-0.06	0.02	0.04	0.01

[a] see table 2 for description.

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Table 4. Analysis of variance for stability for different characters.

Source	df	Mean square									
		Plant height (cm)	Leaf area at 50% flowering (cm^2)	Fresh weight of the inflorescence (g)	Number of rachis per inflorescence	Length of the rachis per inflorescence (cm)	Number of secondary branches per inflorescence	Grain yield per plant (g)	Grain yield per plot (g)	Protein content (g/100g)	Total carbohydrate content (g/100g)
Genotype (G)	9	633.77**	1089419.28**	3091.02**	192.90**	208.40**	11.55**	148.58**	112285.54**	11.34**	236.99**
D + G × D	30	111.64**	5061.27**	395.23**	40.11**	13.50**	0.46**	6.56**	17296.53**	0.02	0.50
Density (D) (linear)	1	814.85**	11388.21**	400.10**	91.57**	102.88**	3.59**	53.53**	360577.96**	0.05	5.73
G × D (linear)	9	107.36**	2782.23**	54.44**	36.58**	17.95**	0.63**	23.08**	8447.46**	0.02	0.72
Pooled deviation (non-linear)	20	78.41**	5770.47**	548.34**	39.12**	7.02**	0.23**	5.78**	4114.53**	0.02	0.14
Pooled error	80	36.94	2408.96	106.77	14.23	3.41	0.08	1.56	2219.52	0.11	0.85

** Significat at 1 % level.

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Table 5. Pooled mean analysis of variance over four plant density levels for different characters.

		Mean squares									
Source	df	Plant height (cm)	Leaf area at 50% flowering (cm^2)	Fresh weight of the inflorescence (g)	Number of rachis per inflorescence	Length of the rachis per inflorescence (cm)	Number of secondary branches per inflorescence	Grain yield per plant (g)	Grain yield per plot (g)	Protein content (g/100g)	Total carbohydrate (g/100g)
Genotype (G)	9	633.77**	108949.28**	3091.02**	192.90**	208.40**	11.55**	1337.29**	112285.54**	11.34**	236.99**
Density (D)	3	271.62**	3797.74**	133.42**	30.51**	34.29**	1.19	53.53**	120192.35**	0.02	1.91
G × D	27	93.87**	5201.668**	424.32**	41.18**	11.19**	0.38	143.46**	5863.66**	0.02	0.34
Error (Pooled)	80	34.94	2408.96	106.77	14.23	3.41	8.71	1.56	2219.52	0.11	0.85

** Significant at 1 % level.

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Table 6. Estimates of stability parameters for plant height, leaf area at 50% flowering and number of rachis per inflorescence.

Genotype	Plant height (cm)			Leaf area at 50% flowering (cm^2)			Number of rachis per inflorescence		
	Mean (*Pi*)[a]	*b*	$\overline{S^2}d$	Mean (P_i)	*b*	$\overline{S^2}d$	Mean (*Pi*)	*b*	$\overline{S^2}d$
RMA 3	85.90 (8.97)**	1.56	48.04	1034.84 (-249.730)	1.60	-369.67	36.11 (15.07)	2.69	6.77
BGA 2	74.49 (-2.44)	1.35	-12.94	826.35 (-458.220)	1.00	-1159.88	45.49 (-5.69)	0.36	-2.79
E C 519554	96.21 (19.28)**	-0.69	142.87**	2246.07 (961.50)**	-2.24	26399.18**	54.65 (3.47)**	-1.81	20.23
SKNA 21	84.54 (7.61)**	3.57	187.31**	1397.42 (112.55)**	2.90*	-1510.55	52.91 (1.73)**	0.64	82.57**
Annapurna	89.78 (12.85)**	1.48	37.60	908.11 (-376.46)	0.88	-1307.66	51.16 (-0.02)	-0.16	24.15
SKNA 601	80.76 (3.83)**	0.22	118.95**	958.70 (-325.870)	-0.10	-2402.12	60.5 1(9.33)**	5.22	41.03
GA 2	69.84 (-7.09)	0.92	-24.70	1915.58 (631.01)**	2.86**	-1390.07	59.20 (8.02)**	1.98	13.52
RMA 4	69.01 (-7.92)	0.88	-32.27	893.91 (390.66)	1.00	-1131.55	50.34 (-0.84)	-0.15	10.78
I C 415290	58.08 (-18.95)	0.03	16.94	1800.51 (515.940)**	2.20	-17522.74**	52.64 (1.46)	-0.58	67.64**
PRA 2004-2	60.72 (-16.21)	0.65	33.27	864.179 (-420.40)	-0.12	-1035.32	48.82 (-2.36)**	1.78	46.69**
Grand mean	76.93	-	-	1284.57	-	-	51.18	-	-

** Mean significantly above the grand mean in desirable direction at 1% level.
[a] Values in parenthesis indicate phenotypic index (*Pi*).

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Table 7. Estimates of stability parameters for length of the rachis per inflorescence, number of secondary branches per inflorescence and fresh weight of the inflorescence.

Genotype	Length of the rachis per inflorescence (cm)			Number of secondary branches per inflorescence			Fresh weight of the inflorescence (g)		
	Mean (P_i)[a]	*b*	$\overline{S^2d}$	Mean (*Pi*)	*b*	$\overline{S^2d}$	Mean (P_i)	*b*	$\overline{S^2d}$
RMA 3	47.51 (3.28)**	1.48	3.31	4.82 (-0.16)	1.17	-0.03	81.09 (-12.67)	0.22	-68.54
BGA 2	45.37 (1.14)**	2.58	14.29**	4.64 (-0.34)	-0.45	0.69**	82.04 (-11.72)	2.19	1401.24**
E C 519554	34.97 (-9.26)	0.85	12.97**	6.03 (1.05)**	3.26*	-0.07	135.37 (41.61)**	-0.76*	487.95**
SKNA 21	36.30 (-7.93)**	3.24*	0.70	3.86 (-1.12)	1.23	-0.01	106.45 (12.69)**	2.19	1002.84**
Annapurna	51.07 (6.77)**	2.17	5.45	9.42 (4.44)	2.77*	0.04	141.06 (47.30)**	2.20*	1049.81**
SKNA 601	51.96 (7.73)**	0.51	-3.08	3.93 (-0.05)	0.82	0.01	81.38 (-120.38)	2.31	345.65**
GA 2	51.95 (7.72)**	-0.13	-1.24	4.48 (-0.5)	-1.28	0.24	99.86 (6.10)**	1.07	-49.74
RMA 4	32.45 (-11.78)**	0.68	-2.46	3.62 (-0.36)	0.51	-0.55**	73.06 (-20.17)	0.78	-8.11
I C 415290	45.98 (1.75)**	-0.30	0.65	4.74 (-0.22)	0.98	0.39	65.21 (-28.77)	-0.10	-74.01
PRA 2004-2	44.79 (0.56)**	-0.07	5.55	4.29 (-0.69)	0.95	0.25	60.50 (-33.26)	-0.11	328.63**
Grand mean	44.23	-	-	4.98					

*, ** Mean significantly above the grand mean in desirable direction at 5 and 1% levels.
[a] Values in parenthesis indicate phenotypic index (*Pi*).

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Table 8. Estimates of stability parameters for grain yield per plant, total carbohydrate content and fresh weight of the protein content.

Genotype	Grain yield per plant (g)			Total carbohydrate content (g / 100g)			Protein content (g/100g)		
	Mean (P_i)	*b*	$\overline{S^2d}$	Mean (*Pi*)	*b*	$\overline{S^2d}$	Mean (P_i)	*b*	$\overline{S^2d}$
RMA 3	11.29 (2.83) [a]	0.01	1.11	31.44 (-3.58)	1.64	-0.63	12.36 (-0.05)	1.31	-0.11
BGA 2	8.95 (-5.17)	0.33	4.80**	37.94 (2.92)**	-0.98	-0.84	15.43 (3.02)**	-3.22	-0.03
E C 519554	23.52 (9.40)**	1.08	7.04**	46.28 (11.26)**	0.19	-0.82	11.27 (-1.14)	1.56	-0.07
SKNA 21	12.40 (-1.72)	1.24	-0.08	27.05 (-7.970	0.92	-0.80	10.56 (-1.85)	3.83	-0.15
Annapurna	23.94 (9.82)**	1.26	-1.30	26.83 (-8.19)	0.42	-0.72	14.51(2.10) **	0.28	-0.06
SKNA 601	19.17 (5.05)**	0.85	18.98*	38.03 (3.01)**	1.31*	-0.84	11.51(-0.90)	3.02	-0.09
GA 2	17.34 (3.22)**	1.46	5.37**	46.93 (11.91)**	0.93	-0.82	12.49 (0.08)**	2.04	-0.04
RMA 4	13.54 (-0.580	2.09	6.48**	38.67 (3.65)**	0.54	-0.60	11.68 (-0.73)	0.04	-0.08
I C 415290	8.16 (-5.96)	-0.21	-0.90	26.48 (-8.54)	3.27*	-0.13	13.87 1.46)**	1.23	-0.02
PRA 2004-2	7.61 (6.51)	1.86	0.76	30.09 (-4.93)	1.73	-0.64	10.46 (-1.95)	-0.10	-0.05
Grand mean	14.12			34.97			12.41		

, * Mean significantly above the grand mean in desirable direction at 5 and 1% levels.
[a] Values in parenthesis indicate phenotypic index (*Pi*).

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Table 9. Estimates of stability parameters for grain yield per plot.

Genotype	Grain yield per plot (g)		
	Mean (P_i)[a]	*b*	S^2d
RMA 3	277.36 9 (-94.84)	0.85	-1639.64
BGA 2	216.17 (-156.03)	0.52	1336.42
E C 519554	608.22 (236.02)**	1.80	7356.89**
SKNA 21	314.48 (-57.72)	0.69	-1068.21
Annapurna	626.85 (254.65)**	1.70	-1757.52
SKNA 601	516.82 (144.62)**	1.14	14742.24**
GA 2	444.61 (72.41)**	1.34	-1010.53
RMA 4	337.89 (-34.31)	0.86	3991.50
I C 415290	219.20 (-15.30)	0.70	-1709.28
PRA 2004-2	160.83 (-211.37)	0.37	-1291.76
Grand mean	372.24		

** Mean significantly above the grand mean in the desirable direction at 1%.
[a]Values in parentheses indicate the phenotypic index (*Pi*).

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Table 10. Score chart for stability parameters of genotypes for thirteen characters.

Genotype	PH[a]	LAF	FWI	NR	LR	NSB	GYP	GYPP	TCC	PC	Combined score for m, r, d
RMA 3	r, d	r, d	r, d	r, d	m, r, d	r, d	r, d	r, d	r, d	r, d	1
BGA 2	r, d	r, d	r	r, d	m, r	r	r	r, d	m, r, d	m, r, d	2
E C 519554	m, r	m, r	m	m, r, d	r	m, d	m, r	m, r	m, r, d	r, d	2
SKNA 21	r	m, r, d	m, r	m, r	m, d	r, d	r, d	r, d	r, d	r, d	1
Annapurna	m, r, d	r, d	m	r, d	m, r, d	d	m, r, d	m,r,d,	r, d	m, r, d	**5**
SKNA 601	m, r	r, d	r	m, r, d	m, r, d	r, d	m, r	m, r,d	m, d	r, d	3
GA 2	r, d	d	m, r, d	m, r, d	m, r, d	r, d	m, r	m, r	m, r, d	m, r, d	**5**
RMA 4	r, d	m, r	r, d	r, d	m, r, d	r	r	r , d	m, r, d	r, d	2
I C 415290	r, d	r	r, d	r	m, r, d	r, d	r, d	r, d	m, d	m, r, d	2
PRA 2004-2	r, d	r, d	r	r	m, r, d	r, d	r, d	r, d	r, d	r, d	1
Combined score for m,r,d	1	1	1	3	7	-	1	2	4	4	7,4,4

'm' = High (desirable) mean; r = 'b' around unity; d = S^2d around zero; (not significant 'b' value); (not significant S^2d value).

[a] PH = plant height; DFF = days to 50% flowering; LAF= Leaf area at 50% flowering; LI = Length of the primary inflorescence; DI= Diameter of the inflorescence; FWI= Fresh weight of the inflorescence; NR= Number of rachis per inflorescence; LR= Length of the rachis per inflorescence; NSB= Number of secondary branches per inflorescence; GYP= Grain yield per plant; GYPP= Grain yield per plot; TCC= Total carbohydrates content; PC; Protein content

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Table 11. Genotypes showing stability for traits.

Character	Genotype
Plant height	Annapurna
Leaf area at 50% flowering	SKNA 601
Fresh weight of the inflorescence	GA 2
Number of rachis per inflorescence	E C 519554, SKNA 601, GA 2
Length of the rachis per inflorescence	RMA 3, Annapurna, SKNA 601, GA 2, RMA 4, I C 415290, PRA 2004 - 2
Number of secondary branches per inflorescence	-[a]
Grain yield per plant	Annapurna
Grain yield per plot	Annapurna, SKNA 601
Total carbohydrate content	BGA 2, E C 519554, GA 2, I C 415290
Protein content	BGA 2, Annapurna, GA 2, I C 415290

[a] "-" indicates that the trait did not show stability across plant densities.

Table 12. Genotypic correlation for characters at the plant densities

Character	Grain yield per plant	Diameter of primary inflorescence	Length of inflorescence	Fresh weight of inflorescence	Number of secondary branches per inflorescence
			Very high plant density (D_1 = 30 × 20 cm)		
Plant height	0.757**				
Length of primary inflorescence	0.694*		0.820**		
Fresh weight of inflorescence	0.817**			0.636*	
			High plant density (D_2 = 30 × 30 cm)		
Fresh weight of inflorescence				0.648*	
Length of					

ISSN 2053-5805(Print), ISSN 2053-5813(Online)

primary inflorescence		0.666*		
		Normal plant density (D_3 = 45 × 20 cm)		
Plant height		0.830**	0.716*	
0.687*	0.728*			
Fresh weight of inflorescence		0.638*	0.808**	
0.783**				
		Low plant density (D_4 = 45 × 30 cm)		
Fresh weight of inflorescence			0.701*	
0.652**				

*,** significant at 5 and 1% levels, Pearson Correlation Coefficient.

Table 13. Direct (diagonal) and indirect effects of component characters on grain yield.

	r_g [a] with grain yield		
	Plant density		
Character	Very high[b]	Normal	Low
Length of primary inflorescence	0.694*		
Fresh weight of inflorescence	0.817* 0.783*	0.652**	

*,** significant at 5 or 1% levels.

[a] r_g = Genotypic correlation.

[b] Very high density (D_1 = 30 × 20 cm) residual effect = 0.332; Normal plant density (D_3 = 45 × 20 cm) residual effect = 0.415, and Low plant density residual effect = 0.559. There were no significant responses at the High plant density (D_2 = 30 × 30 cm).

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