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Full Length Research Paper

'G X E interaction for grain yield and its contributing traits in grain amaranthus

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In grain amaranthus (*Amaranthus hypochondriacus*L.*)* ten genotypes were evaluated for ten characters under four plant density levels *viz.,* very high (D_1), high (D_2), normal (D_3) and low plant density (D_4) levels to study the stability parameters. The study was conducted at Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal during November 2007 to 2008. The results revealed that, the genotypes Annapurna was identified as stable genotype for grain yield in all the four plant density levels. The genotypes BGA 2, GA 2 and IC 415290 recorded stable performance for total carbohydrates and protein content and could be utilized for improvement of these traits in breeding programme. The genotype GA 2 showed stable performance for fresh weight of the inflorescence, an important trait influencing the grain yield in all the four plant density levels. Similarly, SKNA 601 can be chosen as stable genotype for leaf area at 50% flowering, an important selection parameter for yield improvement in all the plant density levels. Among the characters studied, length of the rachis per inflorescence, total carbohydrates and protein content were found to be relatively stable in all the four plant density levels.

Key words: Grain amaranthus, stability parameters, selection.

INTRODUCTION

Grain amaranth (*Amaranthus hypochondriacus* L.) is a traditional crop of himalayan region generally cultivated as a mixed crop as well as part of subsistence agriculture in the hilly areas with comparatively lower rainfall under neglected agriculture conditions. With advent of green revolution, the cultivation of this crop has seen a conspicuous decline mainly due to the lack of awareness of its complementary nutritive value, non-availability of suitable high yielding varieties and lack of improved production techniques. To reverse this declining trend of cultivation, quick varietal improvement is being used as one of the important criteria in increasing the yield potential of this crop. Apart from that, traditionally this crop was grown by broadcasting the seeds thereby resulting in very low yield. Henderson et al. (1993) emphasized that adoption of scientific cultivation practices including proper plant densities and other inputs are essential in maximizing grain yield. In this context, there is an imperative need for the breeders to evaluate and identify the stable genotypes that could give standard performance when tested under different plant density levels. Population density is a major environmental factor influencing the genetic parameters among the characters. Study of the extent of such influence of different plant density levels in these genetic parameters is required to formulate appropriate breeding strategies. Exploitation of heterosis and success in getting desirable segregants in breeding progarmme also depends to a greater extent on the degree of genetic divergence between the parents chosen. Further the genotypes should also perform stably

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Table 1. Details of the genotypes studied.

S/N	Genotypes	Source	Status
1	RMA 3	Rajastan	Released variety
2	BGA 2	NBPGR	Released variety
3	E C 519554	NBPGR	Breeding line
4	SKNA 21	Gujarat	Released variety
5	Annapurna	New Delhi	Released variety
6	SKNA 601	Gujarat	Released variety
7	GA 2	Gujarat	Released variety
8	RMA 4	Rajastan	Released variety
9	I C 415290	NBPGR	Breeding line
10	PRA 2004 - 2	NBPGR	Breeding line

National Bureau of Plant Genetic Resources (NBPGR).

Table 2. Description of different plant density levels.

Density levels				
Particulars	D_1 – very high density	D_2 – high density	D_3 – normal density	D_4– low density
Spacing	30 × 20 cm	30 × 30 cm	45 × 20 cm	45 × 30 cm
Plant population / m^2	50 plants	33 plants	30 plants	22 plants
Plant population / ha	5,00,000 plants	3,33,000 plants	3,30,000 plants	2,22,222 plants

under different environments for seed yield and other contributing characters. Realization of normal yields in amaranthus depends on wider spacing and optimum population density. Grain amaranthus genotypes capable of giving stable yield under different population densities are still lacking. Therefore, this present investigation was carried out to identify stable genotypes with high yield using the Eberhart and Russell (1966) model.

MATERIALS AND METHODS

The materials used in the present study comprised of ten genotypes of grain amaranthus received from the germplasms of National Bureau of Plant Genetic Resources (NBPGR) maintained at the University of Agricultural Sciences, Bangalore and Forestry College and Research Institute, Mettupalayam (Table 1).

The crop was raised during November, 2007 in a randomized block design with three replications. Each genotype was raised in a bed size of 2 m × 1.5 m. The seeds were sown in line. The plants were thinned 15 days after sowing to maintain different levels of spacing *viz*., very high density (30 × 20 cm), high density (30 × 30 cm), normal density (45 × 20 cm) and low density (45 × 30 cm) (Table 2). The recommended packages of practices were followed as per the TNAU Crop Production Guide (2005). Observations were recorded on five randomly selected plants of each genotype in each replication under different population densities for ten characters *viz.,* plant height, leaf area at 50% flowering, fresh weight of the inflorescence, number of rachis per inflorescence, length of the rachis per inflorescence, number of secondary branches per inflorescence, grain yield per plant, total carbohydrates and protein content were analysed. For quality traits, composite samples drawn from five random plants of genotypes under different population densities were used for analysis. The method suggested by Eberhart and Russell (1966) was followed to estimate the three parameters of stability namely mean (x), regression coefficient (b) and mean square deviation (S^2d) for each genotype. In addition, environmental index (I_j) and phenotypic index (*Pi*) were also estimated from the mean data averaged over replications in the environments.

RESULTS AND DISCUSSION

Development of stable varieties is the avowed mission of the plant breeders. A stable genotype is one that has low genotype x environment interaction for agronomically important characters. Hence, assessment of G × E interaction becomes a prerequisite to identify phenotypically stable genotypes. Regression analysis of G × E interaction is considered a sound proposition to characteristic genotypic response to varied environments (Sharma et al., 1998).

Table 3. Values of environmental indices for different traits.

Character	Density levels			
	Very high density	High density	Normal density	Low density
Plant height (cm)	4.64	-4.06	4.35	-4.95
Leaf area at 50% flowering (sq.cm)	-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	-148.25
Total carbohydrate content (g / 100 g)	0.39	0.34	-0.23	-0.50
Protein content (g / 100 g)	-0.06	0.02	0.04	0.01

Eberhart and Russell (1966) extended this approach and included the deviation from the regression as an additional parameter. Eberhart and Russell model is obviously the most informative, balanced and statistically simple one. Hence, it is widely used by the plant breeders to detect high yielding stable genotypes. Using this model, an attempt was made in the present study to identify stable high yielding grain amaranth genotypes which could have general adaptedness to the four plant density level *viz.,* very high, high, normal and low plant density levels.

Sharma et al. (2001); Varalakshmi and Pratapreddy (2002); Varalakshmi (2003); Sudhir and Singh (2003) and Kishore et al. (2007) observed significant difference for environments as well as for G × E interaction for yield and its component traits in their studies in grain amaranthus. In the present investigation also, the pooled analysis of variance indicated that the environments represented by different plant density levels and G × E interaction showed significant difference for all the characters studied, except number of secondary branches per inflorescence, protein content, total carbohydrates, days to 50% flowering, length of the primary inflorescence and diameter of the inflorescence (Tables 3 and 4).

The G × E interaction effect was further partitioned into linear (predictable) and non linear (unpredictable) components through analysis of variance for stability. E + (G × E) interaction was significant for all the characters, except total carbohydrates and protein content. The differential effects of environments on genotypes were found to be significant for all the characters, except aforementioned characters, as indicated by environment (linear) mean squares. The linear component of G × E interaction was significant for plant height, leaf area at 50% flowering, fresh 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, thus indicates the prediction about the performance of most of the genotypes appeared feasible for these characters. The non-significant G × E (linear) component for remaining characters indicated that the genotypic response for these characters under different plant density levels could not be predicted. The significant mean squares due to pooled deviation observed for all the characters, except length of the primary inflorescence, diameter of the inflorescence, days to 50% flowering, total carbohydrates and protein content indicated that the genotypes differed considerably with respect to their stability, representing the unpredictable component of G × E interaction.

Environmental indices computed for the characters revealed that normal density provided favourable environment for the expression of all the characters studied except days to 50% flowering and total carbohydrates in the desirable direction. The protein content registered favorable expression in all plant density levels except at very high density level. The environmental indices indicate that the length of the primary inflorescence, fresh weight of the inflorescence, number of rachis per inflorescence, grain yield per plant, grain yield per plot and protein content showed favorable expression under normal and high plant density levels.

As mentioned earlier, Eberhart and Russell (1966) used the three stability parameters *viz.,*(i) genotypic mean (g_i), expressed as phenotypic index (Pi), (ii) regression value (b) (predictable linear response) and deviation from linearity (S^2d) (unpredictable nonlinear response). According to this model, an ideal stable genotype is one which confirms to the following framework of the three stability parameters: (i) phenotypic index is more than zero, represented by high genotypic mean (Pi > 0 that is, g_i> x), (ii) regression coefficient is equal to unity (b = 1) and (iii) deviation from regression is equal to zero (S^2d = 0) (Tables 5 to 9). Such a genotype would be suitable for general adaptation over all environmental conditions. Using this criterion, a score chart was prepared for all the genotypes for all the characters. Three kinds of score *viz.,* 'm' for significantly

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 ofthe 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 / 100 g)	Total carbohydrate content (g / 100 g)
Genotype	9	633.77**	1089419.28**	3091.02**	192.90**	208.40**	11.55**	148.58**	112285.54**	11.34**	236.99**
Environment + genotype x environment)	30	111.64**	5061.27**	395.23**	40.11**	13.50**	0.46**	6.56**	17296.53**	0.02	0.50
Environment (linear)	1	814.85**	11388.21**	400.10**	91.57**	102.88**	3.59**	53.53**	360577.96**	0.05	5.73
Genotype x environment) (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

*Significance at 1% level.

Table 5. Pooled analysis of variance over four plant density levels 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 / 100 g)	Total carbohydrate (g / 100 g)
Genotype	9	633.77**	108949.28**	3091.02**	192.90**	208.40**	11.55**	1337.29**	112285.54**	11.34**	236.99**
Environment	3	271.62**	3797.74**	133.42**	30.51**	34.29**	1.19	53.53**	120192.35**	0.02	1.91
Genotype x Environment	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

**Significance at 1% level.

Table 6. Estimates of stability parameters for plant height (cm), leaf area at 50% flowering (cm^2) and number of rachis per inflorescence.

Genotype	Plant height (cm)			Leaf area at 50% flowering (cm^2)			Number of rachis per inflorescence		
	Mean (*Pi*)	*b*	S^2d	Mean (P_i)	*b*	S^2d	Mean (*Pi*)	*b*	S^2d
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

Table 6 Contd.

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	-	-

Values in parenthesis indicate phenotypic index (*Pi*) **Mean values significantly above the grand mean in desirable direction.

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

Genotype	Length of the rachis per inflorescence (cm)			Number of secondary branches per inflorescence			Fresh weight of the inflorescence (g)		
	Mean (P_i)	*b*	S^2d	Mean (*Pi*)	*b*	S^2d	Mean (P_i)	*b*	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					

Values in parenthesis indicate phenotypic index (*Pi*) **Mean values significantly above the grand mean in desirable direction.

Table 8. Estimates of stability parameters for length of the rachis per inflorescence (cm), number of secondary branches per inflorescence and fresh weight of the inflorescence (g).

Genotype	Grain yield per plant (g)			Total carbohydrate content(g / 100 g)			Protein content (g / 100 g)		
	Mean (P_i)	*b*	S^2d	Mean (*Pi*)	*b*	S^2d	Mean (P_i)	*b*	S^2d
RMA 3	11.29 (2.83)	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

Table 8 Contd.

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		

Values in parenthesis indicate phenotypic index (*Pi*) **Mean values significantly above the grand mean in desirable direction.

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

Genotypes	Grain yield per plot(g)		
	Mean (P_i)	*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		

Values in parenthesis indicate phenotypic index (*Pi*) * **Mean values significantly above the grand mean in desirable direction.

higher (desirable) mean (that is, Pi is more than zero), 'r' for 'b' value not significantly deviating from unity (that is, b = 1) and 'd' for S^2d value not significantly deviating from zero (that is, S^2d = 0) were used. A combined score chart was computed for all the ten genotypes for thirteen characters.

Combined score chart was computed for all the characters for ten genotypes (Table 10). The combined score chart revealed that Annapurna and GA 2 is the stable genotypes as it scored three parameters together for five traits including grain yield per plant as well as grain yield per plot. The only other genotype which recorded the three parameters together for grain yield per plot is SKNA 601. Hence, Annapurna followed by SKNA 601 could be judged as stable genotype. Besides, Annapurna was earlier identified as the best genotype for all the four plant density levels based on its mean performance. Sharma et al. (1998, 2001) and Kishore et al. (2007) also identified this genotype as the stable variety based on its performance in their study.

Though the genotype GA 2 scored five, it had no stable performance for grain yield even though it registered stable performance on fresh weight of the inflorescence and number of rachis per inflorescence. It could also observed from the combined score chart that almost all the ten characters under study are unstable among the

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

Genotype	PH	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 C519554	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 C415290	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(Non significant 'b' value) (Non significant S^2d value).

Table 11. Genotypes showing stability for different traits.

Character	Genotype	
Plant height	Annapurna	
Leaf area at 50 per cent 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	-	
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	

four plant density levels. The trait length of the rachis per inflorescence recorded stable performance in seven genotypes. Total carbohydrates and protein content also showed stable performance in four genotypes. Grain yield per plant and per plot yield were stable only in one and two genotypes, respectively.

Number of rachis per inflorescence recorded three parameters together for three genotypes. No genotype recorded the stability parameters for number of secondary branches per inflorescence, diameter of the inflorescence, length of the primary inflorescence and days to 50% flowering which reveals that these characters are highly unstable and heavily influenced by the plant density levels. Whereas the other traits like plant height, leaf area at 50% flowering, fresh weight of the inflorescence, number of rachis per inflorescence, length of the rachis per inflorescence, grain yield per plant, grain yield per plot, total carbohydrates and protein content showed stability parameters in only one of the ten genotypes studied.

Details of genotypes showing stability for different traits are listed in Table 11. As discussed earlier, the genotype Annapurna showed stable performance for grain yield per plot and also it

showed stability for the traits grain yield per plant, plant height, length of the rachis per inflorescence and protein content. None of the other genotypes had stability for grain yield per plot except SKNA 601. For quality characters of total carbohydrates and protein content, the genotypes BGA 2, GA 2 and IC 415290 could be exploited being stable performance.

Similarly, stable performance was noticed in seven genotypes *viz.*, RMA 3, Annapurna, SKNA 601, GA 2, RMA 4, IC 415290 and PRA 2004-2, for length of the rachis per inflorescence. This trait was earlier identified as an important yield contributing character in all plant density levels except very high density level in correlation studies and path analysis. Hence, these genotypes may be recommended for these density levels, to realize stable yield. The genotype SKNA 21 had stability for leaf area at 50% flowering which may be used for improvement of yield in breeding programme.

In conclusion, the present study revealed that the genotype Annapurna expressed stable performance on grain yield in all four environments studied and also showed stability for plant height, length of the rachis per inflorescence and protein content. Among the characters studied, length of the rachis per inflorescence, total carbohydrates and protein content were found to be relatively stable in all the four plant density levels.

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