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Full Length Research Paper

Genotype and environmental interaction of plant breeders in developing improved varieties of elephant foot yam

Raman Rushidie[1]*, Bal Chopra Kumar[2], Ambani Bshole Tata[3] and Akbar Singh Ratan[4]

[1]KVK, CAU, C.V. Sc & AH, Selesih, Aizawl-796 014, Mizoram, India.
[2]NDUAT, Kumarganj, Faizabad U.P. -224 229, India.
[3]Department of Horticulture (Vegetable and Floriculture), Bihar Agricultural University, Bhagalpur, Bihar -813 210 India.
[4]ICAR-RC-NEH Region, Mizoram Centre, Kolasib, Mizoram -796 081 India.

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Genotypic × environment (G × E) interactions in 35 indigenous line of elephant foot yam (*Amorphophallus paeoniifolius* Dennst Nicolson) were evaluated for two consecutive years of 2007 and 2008 under four environments in randomized block design (RBD) for yield, plant height, weight of corm, size of corm, dry matter and starch content. Mean squares deviation due to environment and environment linear variations were highly significant for all the traits. Linear component of genotype × environment interaction assumed importance for weight of corm, size of corm and yield. Thus, the prediction of the genotypes in the environments appeared to be feasible for all the characters under study. G × E interaction was found to be significant for dry matter and starch content indicating that these quality contributing traits were highly influenced by the change in environment leading to extension of analysis for estimating stability parameters. All traits significantly observed for environment + (genotype × environment) interaction confirming the influence of environment and suggesting the existence of considerable variation among genotypes as well as environments. On the basis of all three stability parameters (xi, bi and S^2di), the genotype NDA-9 possesses high mean, nearer to unit regression and non-significant low deviation from regression. With respect to yield on the basis of all three adaptability parameters, it is evident that the genotype NDA-9 is stable as it possesses high mean, nearer to unit regression and non-significant low deviation from regression. Whereas the highest yielding genotype NDA-35 showed above average sensitivity and low deviation from regression, this genotype could be considered as a suitable for favorable environmental condition.

Key words: Stability analysis, genotypic × environment interaction, adaptability, yield, quality traits, elephant foot yam.

INTRODUCTION

Elephant foot yam (*Amorphophallus paeoniifolius* Dennst Nicolson), an underground stem tuber, is grown as a summer vegetable especially in South India, North East Region, Bihar and Eastern Uttar Pradesh, which is harvested at the time when there is scarcity of vegetable in the market. The world's rapid population growth is demanding increased production and greater diversification of crops. The tuber crops can play a major

*Corresponding author. E-mail: raman212@hotmail.com

role in addressing this issue (Paul and Bari, 2013). Therefore there is a need to intensify activities that relate to better conservation and efficient use of root and tuber genetic resources as well as their stability in the particular environment is also important. Moreover, tubers are very rich in starch and carbohydrate and used for making vegetable curry, pickles and also as supplementary food. Ayurveda emphasizes the use of *A. paeoniifolius* as a food as well as a medicine and denotes the tuber as a ‘‘Mahabhaishajyam’’, that is, superior medicine (Dey et al., 2012). It has been fully supported as a food in preserving health and for treating ailments. Many indigenous Ayurvedic and Unani medicinal preparations are also made using its tubers. It is an important tuber crop that offers excellent scope for adaptation as a cash crop due to its higher yield potential and longer shelf life than other vegetable crops. Yield, a complex character, is depend on number of horticultural traits and is highly influenced by genetic, environmental as well as genotypic × environment interactions. This is only due to differential response of genotypes under various environmental conditions. Some genotypes have potential to perform better under favourable and adverse environments both as comparison to others. Therefore, it is contemporary to find out the adaptability of available genotypes and suitability of environments to realize the yield potential fully.

Normally genotypes exhibit a wide range of variation within and between environments because of genotype x environment interactions. Fluctuating yields in different crop growing situations necessitates the use of stable performing genotypes for higher and stable yields. The genotype × environment interactions are of major importance to the plant breeders in developing improved varieties. Hence, planning for preliminary evaluation to identify stable genotypes of wider adaptability or productive genotypes for a specific environment is important. The present investigation, therefore, was conceived with the objective to study the genotype × environment interaction and to identify the most productive and stable genotype and environment.

MATERIALS AND METHODS

The experimental materials was comprised of 35 diverse genotypes evaluated for G × E interaction analysis in a randomized block design with three replications at two locations for two consecutive seasons of 2007 and 2008. The experiments were conducted (Table 1) at Main Experiment Station (M.E.S.), Department of Vegetable Science, Narendra Deva University of Agriculture and Technology, Narendra Nagar, Kumarganj, Faizabad, U.P., India. The second location was farmer’s field, Haliapur, Sultanpur, U.P., India. Geographically both place fall in North East Gangetic alluvial plains of Eastern U. P., India. In both the locations, corms were planted in the month of February 2006 and 2007 at spacing of 90 × 90 cm in the pit of 60 cm^3. Pre-planting irrigation was given to field after harvesting of the preceding crop and the soil was pulverized at the right tilth and leveled. Well rotten farm yard manure (FYM) at 25t/ ha was thoroughly incorporated in top soil at the time of field preparations. Healthy corms were cut into the pieces of about 300 to 400 g, having at least 2 to 3 buds, treated with Dithane M -45 at 2.0% and monocrotophos at 2.5% for 30 min and dried in shade for 18 h to avoid any incidence of soil borne diseases and insect infestation respectively. The crop was fed with $N:P_2O_5:K_2O$ at 120:60:80 kg/ ha which was supplied by urea, single super phosphate and muriate of potash, respectively. Whole amount of phosphorus and potassium were applied as basal application. The nitrogen was applied in two equal split doses (60 kg + 60 kg/ ha), half at the time of planting and remaining half at the time of earthing up. A light irrigation was given to each plot immediately after planting and subsequent irrigations were applied as per need. In order to make the field free from weeds, two manual weeding were done at 60 and 90 days after planting followed by earthing up. The crop was harvested in the month of November–December of 2006 and 2007 when leaves turn yellow color and start drying. The corms were dug carefully with the help of spade without any mechanical injury. Five plants were sampled randomly from the main plot for recording data on plant height (cm), weight of corm (kg), size of corm (cm^2), yield (t/ ha), dry matter (%) and starch content (%). The collected data of two years of 2006 and 2007 including four environments (Table 1) and their pooled data were subjected for statistical analysis as per the method of Eberhart and Russel (1966).

RESULTS AND DISCUSSION

On the basis of four environment (E1, E2, E3 and E4), the highest general mean (Table 1) for yield (t/ha) was observed in E2 (25.80 t/ha) followed by E3 (24.68 t/ha). The mean squares for genotypes and environments for all the traits under study were highly significant, suggesting the existence of considerable variation among genotypes as well as environments (Table 2). The genotypic × environment interaction when tested against pooled error was found to be significant for weight of corm, size of corm, dry matter content, starch content and yield, indicating that all the traits were highly influenced by the change in environments leading to extension of analysis for estimating stability. All traits significantly observed for environment + (G × E) interaction confirming the influence of environment and suggesting the existence of considerable variation among genotypes as well as environments. Linear component of genotypic × environment interaction assumed importance and feasibility for weight of corm, size of corm and yield as it was exhibited with significant mean square values, the pooled deviation was found to be significant for dry matter and starch content which confirms the influence of environment on aforementioned traits. Naskar and Singh (1992), Singh et al. (1995) and Kumar et al. (2004) also found significant linear and non-linear component interaction in soybean, turmeric and colocasia, respectively.

With respect to yield on the basis of all three adaptability parameters, it is evident that the genotype NDA-9 is stable as it possesses high mean, nearer to unit regression and non-significant low deviation from regression. Whereas the highest yielding genotype NDA-35 showed above average sensitivity and low deviation from regression, these genotypes could be considered as a suitable for favourable environmental condition.

With respect to yield potential (Table 3), five genotypes have bi=1(nearer). While, fourteen genotypes possess > 1 bi

Table 1. Details of environment and pooled mean yield over environments of 35 genotypes in elephant foot yam.

Environments	Year	Location	Geographical location	Temperature range (°C)	Relative humidity range (%)	Total Rainfall (mm)	Average Sunshine (h)	Soil type	Yield (t/ha) general mean	SEd
Environment - 1 (E1)	2006	M. E. S. Kumarganj	26.47°N latitude and 82.12°E longitudes, 113 m above mean sea level	11.4 – 37-3	30.8 – 80.00	866.60	7.08	Saline (pH 8.2)	23.60	2.95
Environment - 2 (E2)	2006	Farmer's field, Sultanpur	26.27°N latitude and 82.07°E longitude, 95 m above mean sea level.	10.9 – 36.5	30.8 – 82.00	866.70	7.11	Sandy loam (pH 7.9)	25.80	0.31
Environment - 3 (E3)	2007	M. E. S. Kumarganj	26.47°N latitude and 82.12°E longitudes, 113 m above mean sea level.	7.3 – 37.5	48.5 – 80.35	587.80	6.01	Saline (pH 8.2)	24.68	2.97
Environment - 4 (E4)	2007	Farmer's field, Sultanpur	26.27°N latitude and 82.07°E longitude, 95 m above mean sea level.	7.3 – 36.5	45.0 – 85.00	587.00	6.03	Sandy loam (pH 7.9)	22.39	3.24

Table 2. Pooled analysis of variance of 12 characters for stability (Eberhart and Russell, 1966) in elephant foot yam.

Source of variation	d.f.	Mean square											
		Plant height	Stem girth	Canopy spread	No. of cormel	Weight of cormel	Size of cormel	Weight of corm	Size of corm	Dry matter	Starch content	Moisture content	Yield
Genotype (G)	34	623.09**	23.21**	1250.98**	30.58**	13630.08**	600.93**	1.47**	412679.37**	15.41**	15.37**	15.40**	217.08**
Environment (E)	3	1806.74**	352.83**	1443.78**	10.71**	46861.56**	2092.67**	0.37**	352448.86**	6.75**	21.40**	6.62**	74.72**
G × E	102	36.08	0.17	103.55	0.71	2698.28**	28.95**	0.032**	8186.31**	1.28**	0.24**	1.28**	0.91**
E (G +E)	105	86.67**	10.25**	141.85**	0.99**	3960.09**	87.91**	0.042**	18022.38**	1.44**	0.85**	1.44	3.02**
E linear	1	5419.86**	1058.50**	4331.22**	32.15**	140590.69**	6278.10**	1.12**	1057351.0**	20.27**	64.23**	20.27**	224.19**
G linear	34	4.74	0.092	122.69**	1.27**	5216.79**	60.76**	0.040**	10592.25**	1.31	0.23	1.30	1.36**
Pooled deviation	70	50.27	0.20	91.30**	0.42	1397.82**	12.67	0.027	6783.75	1.23**	0.24**	1.23**	0.66
Pooled error	272	52.25	9.32	258.71	3.69	2338.37	50.92	0.083	55496.90	0.74	0.21	0.74	14.28

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

and <1 bi and remaining sixteen genotypes which can be grouped as average, above average and below average sensitivity, respectively. The other genotypes of interest are NDA-4, NDA-5, NDA-10, NDA-14 and NDA-17 as these genotypes exhibit higher yield that's mean have stable genotypes for further selection programme.

While, NDA-4, NDA-10 and NDA-14, had below average regression coefficient and non-significant low deviation from regression indicates the instability of the genotypes. The genotypes NDA-5 and NDA-17 with low S^2di and above average response indicate better performance of aforementioned genotypes under favourable environment. In the light of above, could be

Table 3. Stability parameters of yield contributing parameters in 35 genotypes of elephant foot yam evaluated under four environments.

Genotype	Yield (t/ha)			Plant height (cm)			Weight of corm (kg)			Size of corm (cm2)		
	xi	bi	S2di	xi	bi	S2di	xi	bi	S2 di	xi	bi	S2 di
NDA-1	30.87*	1..39	-4.13	1474.17*	0.74	-12380.11	101.11*	0.96	-16.91	2.19*	0.53	-0.03
NDA-2	15.10	0.88	-4.62	938.42	1.19	-17884.80	69.81	0.89	-17.10	0.60	0.41	-0.03
NDA-3	22.85	1.35	-4.60	1172.63	1.02	-15841.45	83.45	0.92	-16.03	1.41	1.99	-0.02
NDA-4	34.95*	0.83	-4.38	1577.42	-0.24	16268.76	102.22*	0.89	-16.30	2.09*	-0.71	0.02
NDA-5	35.91*	1.30	-4.23	1884.46*	1.08	-17462.17	108.30*	1.23	-16.83	2.27*	0.12	0.00
NDA-6	20.28	1.42	-2.79	1191.25	1.85	-12398.78	83.13	1.08	-17.42	1.16	2.79	0.04
NDA-7	15.78	0.79	-4.56	959.67	1.09	-18383.33	73.63	1.02	-17.02	0.74	0.76	-0.02
NDA-8	13.71	0.62	-4.67	957.33	1.30	-17780.99	71.53	1.27	-14.71	0.55	0.40	-0.03
NDA-9	37.13*	1.05	-3.04	2000.94*	1.20	-13263.94	109.96*	1.07	-17.37	2.38*	1.03	0.00
NDA-10	33.93*	0.45	-4.71	1575.00*	-1.84	-4818.69	102.35*	1.01	-14.11	2.03*	-0.46	0.00
NDA-11	27.44*	-0.53	-1.45	1460.83*	1.21	-13598.75	97.26*	1.29	-16.53	1.86*	-0.01	-0.02
NDA-12	27.21*	0.96	-4.40	1462.50*	1.01	-18213.06	90.76	0.78	147.97*	1.88*	0.84	0.02
NDA-13	17.79	1.19	-3.74	1046.67	1.15	8898.77	82.59	1.09	188.87*	0.97	2.30	0.03
NDA-14	35.47*	0.93	-4.49	1852.50*	1.07	-18265.04	105.16*	0.80	12.70	2.18*	0.69	0.02
NDA-15	16.95	1.10	-3.69	1022.50	1.08	-17692.07	74.54	1.15	-16.99	0.92	1.73	0.02
NDA-16	23.99	1.01	-4.54	1418.33	0.98	-11880.37	92.00	1.32	145.91*	1.76*	0.58	-0.02
NDA-17	32.28*	1.59	-3.34	1670.83*	1.09	-17991.66	97.04*	0.78	242.89*	1.96*	-1.36	0.05
NDA-18	15.84	0.62	-4.37	1000.83	0.96	-17612.07	76.84	1.09	61.21	0.75	1.15	-0.03
NDA-19	25.28	0.48	-4.71	1462.50*	1.05	-17149.94	97.21*	1.04	31.15	1.90*	0.32	0.05
NDA-20	15.08	0.93	-4.68	884.17	1.30	5461.06	70.92	0.92	-14.77	0.63	0.64	-0.03
NDA-21	28.63*	2.14*	-0.87	1735.00*	1.34	-15116.70	101.09*	0.90	9.23	2.28*	0.18	-0.01
NDA-22	23.76	0.71	-4.70	1426.67	1.69	-15810.10	82.87	0.72	144.10*	1.72*	0.97	-0.03
NDA-23	18.27	1.47	-4.40	1146.67	1.17	-17601.67	83.17	1.10	259.08*	1.03	2.73	0.04
NDA-24	20.87	1.31	-4.36	1184.58	1.11	-17457.00	81.14	0.89	26.09	1.23	2.83*	0.05
NDA-25	15.03	0.56	-4.64	944.17	1.14	-16782.81	71.34	1.09	-12.86	0.57	0.15	-0.03
NDA-26	21.90	1.29	-4.42	1102.08	1.10	26148.61	83.50	0.76	9.70	1.27	2.67	0.06
NDA-27	29.12*	0.67	-4.71	1527.50*	1.37	6001.85	93.21	0.48	218.57*	1.92*	0.10	-0.02
NDA-28	24.24	0.70	-4.35	1388.17	0.83	-18243.07	87.04	0.97	-13.73	1.77*	0.76	-0.03
NDA-29	27.27*	1.17	-4.39	1487.00*	0.68	-14848.61	100.887	1.04	-12.52	1..90*	-0.06	-0.03
NDA-30	12.79	0.72	-4.40	935.00	1.10	-18058.91	70.38	1.13	-15.75	0..53	0.01	-0.03
NDA-31	25.62*	0.61	-4.76	1470.84*	1.00	-16302.49	92.01	1.04	-16.69	1.60	1.88	-0.02
NDA-32	22.87	1.38	-4.67	1335.00	1.22	-13091.88	86.12	1.00	-13.96	1..53	2.29	-0.01
NDA-33	18.95	1.38	-4.49	1183.33	1.15	-15747.24	78.77	1.11	-16.14	1.06	2.75	0.03
NDA-34	19.62	1.01	-4.62	1182.50	1.15	-15343.90	85.32	1.04	-16.62	1.13	2.74	0.00
NDA-35	37.40*	1.54	-2.40	2035.00*	0.62	-15790.07	112.49*	1.15	-17.01	2.49*	1.26	-0.02
Mean	24.12	1.00		1345.61	1.00		88.54	1.00		1.49	1.00	
SEm	0.47	0.32		47.55	0.47		4.09	0.56		0.10	0.92	
CD at 5%	3.45			201.43			5.88			0.24		

*Significant at 5% level.

concluded that the genotype NDA-9 would be most adaptable and the best suited for wide environmental condition. The genotypes NDA-35 could also give highest yield under appropriate condition.

Considering the stability parameters for plant height (Table 3), the genotype NDA-35 recorded highest mean among the genotypes with bi value higher than the unity and non-significant S^2di values indicating its suitability only for favourable environmental condition (Al-Aysh, 2013).

Higher mean value of NDA-9 over population mean along with almost unity regression coefficient and zero S^2di indicates the average adaptability (Table 3), while genotypes NDA-21, NDA-5, NDA-4, NDA-14 and NDA-10 expressed less than one regression coefficient, higher mean value and non-significant deviation from regression showing the below average adaptability. Moreover, the NDA-35 is showing above average adaptability for weight of corm. The higher mean, unit value bi and zero S^2di values of NDA-5 and NDA-14 possess the attributes of stable genotype over wide range of environments for size of corm. The two genotypes NDA-9 and NDA-21 had high

Table 4. Stability parameters of quality components in 35 genotypes of elephant foot yam under four environments.

Genotype	Dry matter (%)			Starch content (%)		
	xi	bi	S2di	xi	bi	S2di
NDA-1	17.73	4.10	4.16*	14.46*	0.64	-0.07
NDA-2	14.96	-0.74	1.28	9.83	0.83	-0.06
NDA-3	17.43	-1.74	4.64*	12.88	1.04	0.21
NDA-4	20.41*	1.03	-0.22	15.19*	1.04	0.11
NDA-5	20.55*	0.85	0.01	15.38*	0.85	0.01
NDA-6	19.58	1.37	0.45	12.73	1.12	0.14
NDA-7	16.42	-0.13	0.15	10.65	1.39	-0.01
NDA-8	14.02	0.40	-0.07	9.46	1.06	-0.06
NDA-9	21.16*	0.97	-0.24	15.58*	0.66	-0.04
NDA-10	20.29*	0.23	-0.19	14.81*	0.44	0.00
NDA-11	18.50	1.69	0.27	13.77*	0.82	0.10
NDA-12	18.89	2.66	-0.15	13.97*	0.68	-0.06
NDA-13	17.63	1.51	-0.24	11.10	1.13	-0.02
NDA-14	20.48*	1.49	-0.10	15.58*	0.72	-0.05
NDA-15	17.48	1.10	-0.21	11.96	2.05*	5.90*
NDA-16	17.81	4.26*	0.30	12.85	1.28	0.13
NDA-17	20.70*	2.61	-0.05	14.50*	0.61	-0.07
NDA-18	19.12	1.88	0.24	10.70	1.39	-0.02
NDA-19	19.42*	-0.79	0.05	13.70*	0.80	0.07
NDA-20	17.94	-1.23	1.68	10.47	1.45	-0.05
NDA-21	19.51*	0.35	1.49	14.60*	0.26	0.05
NDA-22	18.62	1.81	0.01	12.91	1.32	0.14
NDA-23	17.15	2.44	-0.14	11.24	1.05	-0.06
NDA-24	20.39*	0.00	-0.24	12.70	1.33	0.04
NDA-25	14.95	1.57	-0.23	9.64	1.06	-0.06
NDA-26	17.71	-0.31	-0.17	12.79	1.31	0.09
NDA-27	16.65	2.82	0.88	14.27*	0.67	-0.06
NDA-28	18.03	-1.70	0.52	13.31	1.38	-0.05
NDA-29	16.59	2.99	0.09	14.19	0.71	-0.06
NDA-30	15.97	-1.54	3.93*	9.51	1.14	-0.06
NDA-31	15.80	0.66	4.96*	13.50*	1.16	-0.07
NDA-32	14.92	1.65	0.50	12.81	1.12	0.15
NDA-33	16.14	0.27	-0.10	11.34	1.06	-0.07
NDA-34	17.61	0.84	11.34*	11.38	1.03	-0.07
NDA-35	21.25*	1.65	-0.12	16.90*	0.39	-0.01
Mean	18.05	0.999		12.87	0.999	
SEm	0.64	1.45		0.28	0.36	
CD at 5%	0.71			0.37		

*Significant at 5% level.

mean, bi > 1 with S^2di = 0 which indicates that these genotypes are suitable for favourable environments. However, the genotypes NDA-35 and NDA-4 with high mean values, bi < 1 and S^2di = 0 are most responsive to unfavorable environmental condition. High mean, regression coefficient (bi) around unity and deviation from regression coefficient (S^2_{di}) around zero would found to be better for selection of stable genotype (Balu et al., 2007). Torga et al. (2013) found that the genotype × sowing seasons and genotype × year interactions were of the greatest important, while genotype × location was less important.

With respect to dry matter content (Table 4), significant S^2di values of NDA-2, NDA-30, NDA-31 and NDA-34 indicate that prediction of their performance over environment would not be authentic. However, NDA-1 showed combined bi and S^2di sensitivity which suggests that both linear and non-linear component is responsible for significant genotypic × environment interaction. Genotype NDA-9 possesses higher dry matter (Table 4) along with unity regression coefficient and non-significant S^2di value and shows the most stable genotype under study.

Out of 35 genotypes, 14 showed significantly higher mean performance, while rest others showed lower mean value. All the genotypes showed non- significant regression coefficient and also deviation from regression except NDA-15 which showed combined bi and S^2di sensitivity. On the basis of all three adaptability parameters (xi, bi and S^2di), the genotype NDA-4 was found most stable among all the genotypes having bi value near to unity with the non-significant S^2di value for starch content (Table 4).

In the light of above considering the all three parameters (xi, bi and S^2di), the genotype NDA-9 is stable as it possesses high mean, nearer to unit regression and non-significant low deviation from regression moreover, the highest yielding genotype NDA-35 showed above average sensitivity and low deviation from regression. These genotypes could be considered suitable for favourable environmental condition where as the genotypes NDA-5 and NDA-17 with low S^2di and above average response indicate better performance under favourable environment. It can be concluded that the genotype NDA-9 would be most adaptable and the best suited for wide environmental condition. The genotype NDA-35 could also give highest yield under appropriate condition. Moreover, NDA-4, NDA-5, NDA-10, NDA-14 and NDA-17 performed well under unfavourable environmental condition.

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