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Genetic Variability and Character Association in Taro (*Colocasia esculenta* (L.) Schott.) Under Mid-Hills of Arunachal Pradesh

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Abstract

An experiment was conducted to screen the superior taro genotypes and to identify the genetic divergence of quantitative characters under mid-hill conditions of Arunachal Pradesh. Fourteen taro genotypes were studied for their morphological, growth and yield characters. Taller plants were observed in APTC-1 (120.7 cm) followed by APTC-2. APTC-5 and TRC-2, which were on par in plant girth (17.8 cm) whereas greater number of suckers was seen in APTC-4 (4.5). Number of leaves (4), leaf area index (1.1-1.6), lamina length (24.8-37.2 cm) and breadth (17.8-28.6 cm) were more in APTC-2, APTC-7, APTC-1 and APTC-6 respectively. Cormel yield was significantly higher in APTC-5 (16.1 t ha^{-1}) followed by Muktakeshi (15.1 t ha^{-1}), APTC-1 (15.0 t ha^{-1}) and APTC-2 (14.5 t ha^{-1}), which were on par. The high value of Phenotypic Coefficient of Variation (PCV) along with Genotypic Coefficient of Variation (GCV) indicated that there was more variability in the characters like plant girth, number of side suckers, number of cormels and cormel yield. The high values of genetic advance (GA) coupled with high estimates of heritability suggest that real progress in improvement through selection could be made for yield and associated traits like number of leaves, lamina length and breadth, cormel weight and cormel size. The genotypes APTC-1, 2 and 5 and TRC-2 and 3 could be used for further breeding programmes.

Key words: *Colocasia esculenta*, variability, correlation coefficient, PCV, GCV, path analysis, yield

Introduction

Taro (*Colocasia esculenta* (L.) Schott.) is an allogamous and polymorphic species having thousands of cultivars. Taro is one of the important staple food in almost all tropical and subtropical countries. It is grown widely in Africa, Asia and the Pacific for its corms and cormels, which are nutritionally comparable to potato (Yen and Wheeler, 1968; Beevi et al., 2010). It is grown as a root crop, leafy vegetable and for ornamental purpose. In India, taro is largely grown as a vegetable in North Eastern states, West Bengal, Chhattisgarh, Maharashtra, Andhra Pradesh and Kerala. The corms and cormels are used for making curry, pickle and also as a supplementary food. Humid climate is suitable for this crop and it performs poorly under hot and dry conditions. The edible portion is chiefly rich in carbohydrate with good amount of protein and minerals. In some areas, taro is grown for its tender leaves and petioles, which are edible and contain 23% protein on dry weight basis (Tindall, 1986). Easy and cheaper transport and year-round availability enhances the popularity of this crop as a vegetable. There is scope to improve the yield potential and quality through breeding. Variations with respect to an array of morphological characters, both qualitative and quantitative have been reported in taro (Mehta et al., 2003; Singh et al., 2004; Beevi et al., 2010; Kumar et al., 2010). Genetic variability in terms of growth and yield is a prerequisite for successful breeding. Hence understanding the heritability of traits and their association in the existing germplasm needs thorough examination for yield improvement. The objective of the present study was therefore to examine the extent of variability among the collected genotypes, inheritance and character association for various traits of economic importance suitable for breeding taro for the mid-hill regions.

Materials and Methods

The field experiment was carried out at the experimental farm of ICAR Research Complex for NEH Region, Arunachal Pradesh Centre, Basar, located at West Siang District of Arunachal Pradesh, India, (27° 95′ N latitude and 94° 76′ E longitude, 660 m above mean sea level) during 2008-2009 and 2009-2010. The soil is silty loam, acidic in reaction (pH 5.3), high in organic C (1.5 %), low in available N (205.6 kg ha^{-1}) and available P (8.3 kg ha^{-1}) and medium in available K (260 kg ha^{-1}). Materials of the present study comprised of 14 taro genotypes collected from Arunachal Pradesh and Tripura. The experiment was laid out in Randomized Block Design and replicated thrice. Land was prepared with the help of mould board plough and harrowed twice to pulverize the soil. Well decomposed farmyard manure (10 t ha^{-1}) was added prior to second harrowing and then levelled manually. Corms of each accession were planted in plots of size 3x2 m^2 at a spacing of 60 x 45 cm and a depth of 5 to 6 cm. Light irrigation was given immediately after planting. NPK @ 80:25:100 was applied. One third of N and K along with full dose of P were applied as basal dose and the remaining quantity of N and K was added at monthly intervals in three equal splits. The experimental site was kept free of weeds by periodic hand weeding. Standard cultural practices were followed uniformly for all the accessions. Five plants from each plot were selected at random and tagged. Observations on plant height (cm), plant (pseudostem) girth (cm), number of side suckers, lamina length (cm), lamina breadth (cm), number of leaves and leaf area index were recorded at 4^{th} month of planting. Root characters such as corm length (cm), corm diameter (cm), number of cormels, cormel weight (g) and cormel yield (t ha^{-1}) were recorded after harvest of the selected plants from each plot. Leaf area index (LAI) was measured by the ratio of leaf area (cm^2) to ground area. The pooled data were analyzed for coefficient of variation (Burton and de Vane, 1953), heritability, genetic advance (GA as per cent mean), correlation coefficient (Al-Jibouri et al., 1958) and path coefficient (Dewey and Lu, 1959).

Results and Discussion

Analysis of variance showed that there was significant difference among genotypes for all the characters studied (Table 1). Highly significant mean square showed the prevalence of considerable variation for the traits of interest, among the accessions, which is a pre-requisite for selection of good lines for breeding of taro. Among the 14 genotypes studied, APTC-1 and APTC-2 produced taller plants, whereas TRC-4 produced shortest plants (Table 2). The genotypes

Table 1. Analysis of variance (ANOVA) for various traits among 14 genotypes of taro

Source of variation	df	Plant height	Plant girth	Number of side suckers	Number of leaves	Leaf area index	Lamina length	Lamina breadth	Corm length	Corm diameter	Number of cormels	Cormel weight	Cormel yield
Replication	2	0.06	0.05	0.08	0.04	0.001	0.25	0.24	0.05	0.12	4.96	21.23	0.14
Genotype	13	188.7**	27.41**	1.82*	0.16*	o.074	81.03**	41.91**	1.25*	0.98	170.49**	14974.22**	14.3**
Error	26	38.5	0.12	0.009	0.05	0.01	1.38	1.33	0.17	0.31	0.85	157.28	1.51

* Significant at 5% level, ** Significant at 1 % level

APTC-5 and TRC 2 had greater plant girth whereas the lowest plant girth was observed in APTC-1. Genotypes did not vary significantly in sucker production. However, more suckers were observed in APTC-4 followed by APTC-3. Among the genotypes, there was less variability in terms of total number of leaves per plant and leaf area index. However, lamina length and breadth varied greatly among the genotypes. Higher leaf lamina length and breadth were observed in APTC-5, APTC-1, APTC-3, APTC-7 and APTC-8. Lamina length and breadth of the genotypes, Muktakeshi, Telia, APTC-4 and TRC-1 were almost the same. Corm and cormel characters of taro collections are presented in Table 3. It was found that the genotypes were almost similar in their corm length and diameter. However, the genotypes, Muktakeshi, APTC-1, APTC-5 and TRC-3 produced longer corms, whereas the least was observed in the genotypes, APTC-3, TRC-1 and APTC-8. Corm diameter was more in APTC-8, whereas the minimum was observed in APTC-3. Number of cormels and cormel weight are important yield determining characters of taro. The observed trends may be attributed to the inherent growth character of the genotypes. Nedunchezhiyan et al. (2011) reported that the size and number of corms and cormels were influenced by the endogenous hormone levels in root crops such as elephant foot yam. The differences observed in our study for the root characters among the accessions may be attributed to the hormonal variation in these accessions. Similar findings were reported by Beevi et al. (2010). It is evident from Table 3 that inspite of higher corm length and diameter, APTC-8 was shy in producing cormels. Maximum number of cormels per plant was observed in APTC-2 followed by APTC-4 and Muktakeshi. Though number of cormels per plant was comparatively lower in APTC-5, it out yielded other genotypes due to significantly higher cormel weight. Telia, APTC-5, APTC-6, APTC-7 and TRC-2 were moderate in cormel production. Cormel yield was significantly higher and almost same in APTC-5 (16.1 t ha^{-1}), Muktakeshi (15.1 t ha^{-1}), APTC-1 (15.0 t ha^{-1}) and APTC-2 (14.5 t ha^{-1}).

Table 2. Growth characters of taro germplasm lines under mid-hills of Arunachal Pradesh

Genotypes	Plant height (cm)	Plant girth (cm)	Number of suckers	Number of leaves	Leaf area index	Lamina length (cm)	Lamina breadth (cm)
Muktakeshi	115.3±3.4	10.3±0.15	2.5±0.02	4.1±0.12	1.6±0.01	26.3±0.66	25.4±0.81
Telia	98.6±3.4	11.6±0.17	3.0±0.06	4.0±0.14	1.1±0.03	24.8±0.52	17.8±0.54
APTC-1	120.7±4.8	7.9±0.13	2.1±0.04	4.4±0.06	1.2±0.03	37.2±0.56	22.1±0.25
APTC-2	116.1±4.8	15.4±0.17	1.8±0.03	4.5±0.01	1.3±0.05	30.8±0.81	18.7±0.67
APTC-3	109.5±2.3	10.4±0.21	3.3±0.06	4.3±0.11	1.4±0.02	35.6±0.61	24.3±0.37
APTC-4	112.3±3.7	15.2±0.17	4.5±0.05	4.0±0.10	1.4±0.02	27.7±0.57	17.5±0.36
APTC-5	110.7±3.6	17.8±0.27	2.4±0.12	4.2±0.11	1.6±0.04	43.5±1.15	30.4±0.41
APTC-6	113.5±3.2	13.1±0.15	1.8±0.02	4.2±0.14	1.5±0.05	32.6±0.49	28.6±1.03
APTC-7	110.4±3.1	11.0±0.16	2.7±0.05	3.8±0.17	1.6±0.09	33.9±0.51	22.5±0.26
APTC-8	113.1±3.8	10.2±0.17	2.2±0.04	3.6±0.20	1.5±0.10	32.8±0.75	23.4±0.82
TRC-1	103.6±2.8	15.2±0.26	3.0±0.06	3.9±0.08	1.4±0.06	25.6±0.73	25.9±0.93
TRC-2	106.5±2.0	17.8±0.20	2.8±0.05	4.1±0.17	1.4±0.07	30.3±0.52	29.4±0.88
TRC-3	101.4±3.8	13.2±0.19	2.3±0.06	4.0±0.17	1.4±0.06	26.5±0.40	24.3±0.56
TRC-4	90.7±1.7	14.8±0.23	1.4±0.03	3.8±0.06	1.4±0.05	29.8±0.51	22.4±0.38
CD (0.05)	10.48	0.6	0.163	0.383	0.172	1.986	1.948

Each value is Mean± SD from three replications

Our study indicates the availability of sufficient genetic variability for the economic traits among the genotypes studied which may be exploited in breeding programmes. The mean, range, phenotypic and genotypic variances, PCV, GCV, heritability and genetic advance as per cent mean is presented in Table 4. Range values revealed the greater variation in characters like plant height, girth, lamina length, lamina breadth, number of cormels, cormel weight and cormel yield. It offers great scope for the use of these genotypes for breeding purposes towards yield improvement. Higher genotypic and phenotypic

Table 3. Corm and cormel characters of taro germplasm lines under mid-hills of Arunachal Pradesh

Genotypes	Corm length (cm)	Corm diameter (cm)	Number of cormels per plant	Cormel weight (g plant^{-1})	Cormel yield (t ha^{-1})
Muktakeshi	5.3±0.28	3.56±0.26	28.4±0.87	498.1±15.8	15.1±0.98
Telia	4.8±0.26	3.53±0.20	17.8±0.51	432.5±4.3	13.7±0.54
APTC-1	5.2±0.26	4.03±0.23	23.8±0.99	486.3±8.0	15.0±0.72
APTC-2	5.1±0.26	3.93±0.14	32.6±0.94	476.6±6.3	14.5±0.60
APTC-3	3.7±0.14	2.22±0.93	24.2±0.78	341.5±6.0	10.2±0.40
APTC-4	4.3±0.23	4.13±0.08	28.7±0.87	364.0±3.7	10.7±0.43
APTC-5	5.4±0.23	4.33±0.20	11.7±0.13	539.7±7.8	16.1±0.82
APTC-6	4.1±0.23	3.76±0.31	19.7±0.34	380.1±4.6	11.6±0.75
APTC-7	4.3±0.20	3.80±0.05	15.2±0.35	460.2±4.0	14.1±0.89
APTC-8	3.8±0.26	4.40±0.17	7.8±0.19	321.0±5.1	9.8±0.46
TRC-1	3.7±0.17	2.90±0.05	15.8±0.39	301.3±3.5	9.2±0.31
TRC-2	4.0±0.23	3.63±0.14	17.7±0.57	418.8±4.3	12.6±0.58
TRC-3	5.3±0.23	3.90±0.28	13.9±0.50	431.2±6.1	13.4±0.98
TRC-4	4.9±0.23	3.40±0.23	9.6±0.20	402.6±8.0	12.2±0.64
CD (0.05)	0.705	0.943	1.560	21.165	2.077

Each value is Mean± SD from three replications

Table 4. Estimation of genetic parameters of different characteristics of taro

Character	Mean	Range	$б^2G$	$б^2P$	PCV (%)	GCV (%)	h^2 (%)	GA as % Mean
Plant height	108.72*	90.7-120.7*	50.07	88.62	8.65	6.50	56.4	10.06
Plant girth	13.16*	7.9-15.4*	9.09	9.22	23.08	22.92	98.6	46.86
Number of side suckers	2.56	1.4-3.0	0.60	0.61	30.50	30.27	98.4	61.84
Number of leaves	4.08	3.8-4.5	0.03	0.08	7.33	4.78	42.6	6.08
Leaf area index	1.42	1.1-1.6	0.02	0.03	12.51	10.25	67.0	16.83
Lamina length	31.29*	24.8-43.5*	26.55	27.93	16.89	16.46	95.0	33.05
Lamina breadth	23.66*	17.8-30.4*	13.52	14.86	16.34	15.59	91.0	30.54
Corm length	4.56*	3.7-5.4*	0.36	0.53	16.02	13.16	67.4	22.16
Corm diameter	3.68*	2.9-4.4*	0.22	0.53	19.86	12.83	41.7	16.99
Number of cormels	19.11	7.8-32.6	56.54	57.40	39.62	39.33	98.5	80.44
Cormel weight per plant	417.97**	301.3-539.7**	498.97	506.26	17.07	16.81	96.9	34.09
Cormel yield	12.76***	9.2-16.1***	4.26	5.77	18.84	16.18	73.7	28.58

*cm; **g; ***t ha^{-1}

variances were recorded for plant height, lamina length, number of cormels and cormel weight. Plant height had moderate heritability and low genetic advance due to higher environmental influence on it. The traits having high GCV possessed a higher magnitude of variability and thus presented a better possibility for exploitation in breeding programmes. In general, larger difference between PCV and GCV indicated the greater influence of environmental variables on PCV. The high value of PCV along with GCV indicated that there was more variability in the characters like plant girth, number of side suckers, corm diameter, number of cormels and cormel yield. Plant height and number of leaves showed low PCV and GCV values. Closeness between PCV and GCV indicated that the phenotypic expression of all the genotypes was mostly under genetic control and environment had very limited influence on their expression (Mukherjee et al., 2003; Singh et al., 2004). When high heritability is accompanied with high genetic advance, it indicates additive gene effects and selection may be effective. High heritability with low genetic advance indicates the importance of non-additive gene effects while low heritability accompanied with low genetic advance indicates that the character is highly influenced by environmental factors and selection would be ineffective (Tanimoto, 1990; Xu et al., 2001). In the present study, most of the characters exhibited moderate to high heritability which indicated that the characters were less influenced by the environmental variables and were effectively transmitted to progeny. High heritability estimates were observed for plant girth, number of side suckers, lamina length and breadth, number of cormels and cormel weight. The genetic advance as per cent mean was higher for the characters like plant girth (46.86%), number of side suckers (61.84%), lamina length (33.05%), lamina breadth (30.54%), number of cormels (80.44%) and cormel weight (34.09%). In the present study, high heritability accompanied with higher genetic advance for the characters like number of side suckers, lamina length, lamina breadth, number of cormels, cormel weight and cormel yield suggested the role of additive gene action and thus a high genetic gain is expected on these traits. The low genetic advance (10.06%) for plant height coupled with moderate heritability (56.4%) showed the predominance of non-additive gene action. Similar heritability estimates were observed by Mehta et al. (2003), Singh et al. (2004) in taro and Kumar et al. (2010) in elephant foot yam.

Correlation between characters is successfully employed in breeding of crops by observing the direction and magnitude of association of traits at genotypic and phenotypic levels (Table 5). Correlations ensure simultaneous improvement in one or two or more variables and negative correlations bring out the need to obtain a compromise between the desirable traits. High correlation between two characters indicates that

Table 5. Genotypic (G) and phenotypic (P) correlation coefficients between different pairs of characters in taro

Chara cter		X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
X_1	G	-0.36	0.08	0.83**	0.17	0.48	0.08	0.09	0.50	0.63*	0.29	0.67*
	P	-0.27	0.05	0.69**	0.12	0.34	-0.01	-0.08	0.17	0.54*	0.20	0.61*
X_2	G		0.07	0.01	0.14	0.01	0.24	0.01	0.12	-0.11	0.04	-0.01
	P		0.08	0.01	0.12	0.02	0.23	-0.03	0.09	-0.11	0.03	-0.01
X_3	G			-0.11	-0.17	-0.25	-0.30	-0.40	-0.21	0.30	-0.32	-0.34
	P			-0.07	-0.13	-0.24	-0.29	-0.32	-0.13	0.31	-0.31	-0.31
X_4	G				-0.38	0.30	-0.04	0.44	-0.24	0.87**	0.55	0.69*
	P				-0.19	0.25	0.06	0.21	-0.06	0.57*	0.36	0.64*
X_5	G					0.28	0.68**	-0.13	0.06	-0.25	0.02	-0.06
	P					0.19	0.61*	-0.14	0.06	-0.22	0.02	-0.06
X_6	G						0.30	0.11	0.27	-0.17	0.36	0.34
	P						0.31	0.08	0.18	-0.16	0.36	0.29
X_7	G							-0.22	-0.20	-0.36	-0.02	-0.05
	P							-0.19	-0.06	-0.34	0.01	-0.03
X_8	G								0.62*	0.13	0.91**	0.98**
	P								0.22	0.13	0.75*	0.79**
X_9	G									-0.17	0.69*	0.48
	P									-0.11	0.36	0.34
X_{10}	G										0.20	0.74**
	P										0.20	0.65*
X_{11}	G											0.97**
	P											0.89**

* Significant at 5% level, **Significant at 1 % level

X_1 Plant height; X_2 Plant girth; X_3 Number of side suckers; X_4 Number of leaves; X_5 Leaf area index; X_6 Lamina length; X_7 Lamina breadth; X_8 Corm length; X_9 Corm diameter; X_{10} Number of cormels; X_{11} Cormel weight; X_{12} Cormel yield

Table 6. Estimates of direct and indirect effects of various traits on the yield of different genotypes of taro

Character	Plant height	Plant girth	Number of side suckers	Number of leaves	Leaf area index	Lamina length	Corm diameter	Number of cormels	Cormel weight	Correlation with yield
Plant height	**0.5385**	-0.1976	0.0463	0.4490	0.0950	0.2606	0.2717	0.3430	0.1586	0.61*
Plant girth	-0.0118	**0.0321**	0.0026	0.0001	0.0047	0.0001	0.0040	-0.0037	0.0014	-0.01
Number of side suckers	0.0138	0.0128	**0.1600**	-0.0184	-0.0286	-0.0411	-0.0337	0.0495	-0.0514	-0.31
Number of leaves	0.4150	0.0022	-0.0571	**0.4977**	-0.1923	0.1542	-0.1210	0.4357	0.2764	0.64*
Leaf area index	0.0002	0.0001	-0.0002	-0.0004	**0.0009**	0.0003	0.0001	-0.0002	0.0000	-0.06
Lamina length	-0.2852	-0.0023	0.1512	-0.1826	-0.1681	**-0.5892**	-0.1615	0.1021	-0.2168	0.29
Corm diameter	-0.1257	-0.0314	0.0524	0.0606	-0.0163	-0.0683	**-0.2491**	0.0433	-0.1229	0.34
Number of cormels	-0.6458	0.1154	-0.3139	-0.8875	0.2630	0.1756	0.1760	**0.8538**	-0.2064	0.65*
Cormel weight	0.3581	0.0549	-0.3907	0.6752	0.0355	0.4474	0.5998	0.2476	**1.2158**	0.89**

* Significant at 5% level, ** Significant at 1 % level, Residual effect = 0.3637

selection for the improvement of one character leads to simultaneous improvement of the other character depending upon the magnitude of association between them. In the present study, in general, the estimates of genotypic correlation coefficients were higher than phenotypic correlation coefficient which indicated that the apparent association of two characters was due to governing genes. Correlation studies revealed that plant height had significant positive correlation with number of leaves (r=0.83) and number of cormels (r=0.68). Cormel yield was positively correlated with number of leaves (r=0.69), corm length (r=0.98), number of cormels (r=0.74) and cormel weight (r=0.97). Thus the screening of genotypes based on these taits either in combination or alone would be beneficial to enhance yield potential.

Path coefficient analysis was performed to understand the extent of contribution provided by the traits towards yield (Table 6). The information obtained helps in giving proper attention to the various characters during selection or other breeding programmes so that improvement of desirable traits can be achieved effectively. Highest direct effect among characters was observed with cormel weight (1.2158). Other characters like number of cormels (0.8538), plant height (0.5385) and number of leaves (0.4977) also significantly influenced the yield. The highest negative direct effect was observed for lamina length. The residual effect contributed 0.3637 only. Thus all the traits in the present study contributed to maximum variability towards yield.

The present study revealed the presence of adequate variability, which could be harnessed for developing new varieties with high yield and quality. Based on cormel yield, the genotypes, APTC-5, APTC-1, APTC-2 and cormel weight, the genotypes, TRC-2 and TRC-4 were identified as promising lines for varietal improvement and cultivation. Correlation and path coefficient studies suggested that the selection should be primarily based on the component characters, which exhibited significant positive correlation with yield and also had either direct or indirect effect on yield.

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