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Studies on genetic variability, correlation coefficient and path coefficient analysis for growth and yield attributes in taro (*Colocasia esculenta* L.)

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Abstract
A field experiment was conducted to assess the magnitude of genetic variability present in taro genotypes during *Rabi* 2020-21. The experiment was laid out in randomized complete block design at College of Horticulture, Mudigere. The analysis of data revealed the presence of considerable variability for all the characters among the genotypes. Estimates of high heritability coupled with high genetic advance as per cent over mean recorded for all the traits except leaf thickness, cormel width and protein content suggesting that these characters can be improved through direct selection due to predominance additive gene action. Correlation studies revealed that tuber yield per plant exhibited a highly significant and positive correlation with the plant height, number of leaves per plant, leaf length, petiole length, leaf area, cormel weight, number of corms per plant, number of cormels per plant, corm yield per plant and cormel yield per plant both at genotypic and phenotypic level. Path coefficient analysis revealed that traits like plant height, number of leaves per plant, leaf length, corm yield per plant and cormel yield per plant exhibited positive direct effect on tuber yield per plant both at genotypic and phenotypic level which indicating that direct selection based on these attributes can be used in developing high yielding varieties.

Keywords: Taro, genetic variability, correlation, path coefficient, quality, yield

Introduction

Taro (*Colocasia esculenta* L.) is an herbaceous perennial tuber bearing plant known as eddoe type or arvi belongs to the monocotyledonous family Araceae (Van wyk, 2005) [27]. It is an ancient crop, originated in the Indo-Malayan region probably in Eastern India and Bangladesh (Yen and Wheeler, 1968) [31]. It is believed that the origin of domesticated taro is from wild type *C. esculenta* var. *aquatilis*, either in North East India or South East Asia (Matthews, 1991) [11]. It is also known as "Potato of the Tropics" and grown throughout the tropics and sub-tropics. Taro is one among the few edible species in genus colocasia. Cultivated types are mostly diploid (2n=2x=28) although some triploids are found (2n=3x=42) (Singh *et al.*, 2007) [21].

The corms and cormels of colocasia are used as vegetable after the through cooking because corms are acrid due to the presence of calcium oxalates. The corms of colocasia are rich in starch (70-80%) but contains comparatively low amounts of fat and protein. Colocasia contains water (63-85%), proteins (8-13%), fiber (0.6-1.2%), fats (2.0-4.0%), β-carotene 24 µg, thiamine 0.09 mg, riboflavin 0.03 mg, calcium 40 mg and iron 1.7 mg etc. (Coursey, 1968) [5]. The corms are used for preparation of fermented acidic product *i.e.*, poi and consumed as cooked vegetables or are made into puddings, breads.

Genetic variability available within the taro genotypes has not been fully explored and screened. Crop improvement largely depends on existence of genetic variability. Improvement in any crop is based on the extent of genetic variation present in it and the degree of improvement depends on magnitude of the available, beneficial genetic variability. The critical assessment of nature and magnitude of variability in the germplasm stock is one of the important pre-requisites for formulating effective breeding methods as the genetic improvement of any crop depends on magnitude of genetic variability and the extent of heritability of economically important characters, though the part played by environment in the expression of such character also needs to be taken into account.

Material and Methods

The present investigation was carried out at the Vegetable Science Block in College of Horticulture, Mudigere, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga during the *Rabi* season 2020-21. The experimental material used for the investigation comprised of twenty genotypes of taro (*Colocasia esculenta* L.), which were collected from different places. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

Observations were recorded on five randomly selected plants in each replication for quantitative and qualitative traits *viz*., days to sprouting, plant height (cm), diameter of stem (cm), number of leaves per plant, leaf length (cm), leaf breadth (cm), leaf thickness (mm), petiole length (cm), petiole girth (cm), leaf area (cm^2), leaf area index, corm length (cm), corm width (cm), cormel length (cm), cormel width (cm), number of corms per plant, number of cormels per plant, corm weight (kg), cormel weight (kg), cormel yield per plant (g), corm yield per plant (g), tuber yield per plant (g), herbage yield per plant (g), TSS (°Brix), total sugars (%), reducing sugars (%), non reducing sugars (%), protein content (%), dry matter (%), fiber content (%) and starch content (%). Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation was calculated as per the formula suggested by Burton and Devane (1953) [2]. Heritability (broad sense) and genetic advance was estimated using the formula given by Johnson *et al*. (1955) [8]. Data was analyzed to estimate correlation as well as direct and indirect effects as for 11 different yield attributing characters as per the methods of Al-Jiboure *et al.* (1958) and Dewey and Lu (1959) [7] respectively.

Result and Discussion

Genetic parameters

The genetic factors *viz*., range, mean, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2), genetic advance (GA) and genetic advance as per cent mean (GAM) were calculated and are presented in the Table 1 for growth parameters and for yield, quality attributes are furnished in Table 2.

High values of phenotypic coefficient of variation and genotypic coefficient of variation were recorded for plant height, diameter of stem, number of leaves per plant, leaf length, leaf breadth, petiole length, petiole girth, leaf area, leaf area index, corm length, cormel length, corm weight, cormel weight, number of corms per plant, number of cormels per plant, herbage yield per plant, corm yield per plant, cormel yield per plant, tuber yield per plant, tuber yield per plot, estimated tuber yield, fiber content, TSS, reducing sugars and non-reducing sugars. It indicates the presence of a higher magnitude of variability and less environmental influence on expression for these characters, which would be helpful for further selection. The results were in conformity with findings of Thakur *et al.* (2021) [25] for plant height, corm weight, cormel weight, number of cormels per plant, tuber yield per plant, Sharavati *et al.* (2018) [19] for estimated tuber yield, Kumar *et al.* (2017) [9] for corm length, number of corms per plant, corm yield per plant, cormel yield per plant, Singh *et al.* (2017) [23] for leaf breadth and petiole length, Choudhary *et al.* (2011) [4] for diameter of stem, Cheema *et al.* (2007) [3] for number of leaves per plant, Singh *et al.* (2012) [24] for leaf length, Shellikeri *et al.* (2020) [20] for herbage yield per plant, Nwankwo *et al.* (2019) [14] for leaf area and leaf area index, Paul and Bari (2013) [15] for petiole girth, cormel length, Ramesh *et al.* (2017) [17] for fiber content, Tripathi *et al.* (2016) [26] for TSS, Narasimhamurthy *et al.* (2018) [12] for reducing sugars and non-reducing sugars.

High estimates of heritability coupled with high genetic advance as per cent over mean were recorded for the traits such as days to sprouting, plant height, diameter of stem, number of leaves per plant, leaf length, leaf breadth, petiole length, petiole girth, leaf area, leaf area index, corm length, corm width, cormel length, corms weight, cormel weight, number of corms per plant, number of cormels per plant, herbage yield per plant, corm yield per plant, cormel yield per plant, tuber yield per plant, tuber yield per plot, estimated tuber yield, dry matter content, fiber content, TSS, total sugars, reducing sugars, non-reducing sugars, starch content. This indicates the role of additive gene action and suggests that effective progress in improvement through selection could be achieved for these traits. These results were in agreement with the reports of Kumar *et al.* (2020) [10] for plant height, number of leaves per plant, leaf length, corm width, number of cormels per plant, cormel yield per plant, tuber yield per plot and dry matter content, Narasimhamurthy *et al.* (2018) [12] for petiole length, leaf area, total sugars, reducing sugars, non-reducing sugars and starch content. Narayan *et al.* (2019) [13] for days to sprouting, Singh *et al.* (2012) for diameter of stem, Nwankwo *et al.* (2019) [14] for leaf area index, Thakur *et al.* (2021) [25] for tuber yield per plant, estimated tuber yield, corm weight and cormel weight, Kumar *et al.* (2017) [9] for number of corms per plant, Shellikeri *et al.* (2020) [20] for herbage yield per plant, Singh *et al.* (2017) [23] for leaf breadth, corm yield per plant, Paul and Bari (2013) [15] for petiole girth, corm length and cormels length.

Correlation studies

Correlation analysis provides information on the nature and magnitude of the association of different component characters with tuber yield. It also helps us to understand the nature of inter-relationship among the component traits themselves. Ultimately this kind of analysis could help the breeder to design selection strategies to improve tuber yield, but it alone does not give clear picture of association between the characters. In present study, tuber yield per plant had shown highly significant and positive correlation with plant height, number of leaves per plant, leaf length, petiole length, leaf area, cormel weight, number of corms per plant, number of cormels per plant, corm yield per plant and cormel yield per plant at both phenotypic and genotypic level (Table 3). These could be used as traits of interest for indirect selection to improve total yield per plant in further breeding programme. The results were in accordance with findings of Vimal *et al.* (2019) [28] and Yadav *et al.* (2018) [30].

Table 1: Estimates of mean, range and genetic components of variation for growth parameter in twenty colocasia genotypes.

SI. No	Characters	Mean ± S.Em.	Range	GV	PV	GCV (%)	PCV (%)	h^2 (%)	GA	GAM (%)
1.	Days to Sprouting	28.69 ± 1.36	22.67 – 39.32	17.71	23.26	14.67	16.81	76.15	7.57	26.37
2.	Plant height (cm)	40.53 ± 1.62	17.60 – 73.93	294.93	302.76	42.38	42.93	97.41	34.92	86.16
3.	Diameter of stem (cm)	2.55 ± 0.14	1.55 – 5.41	1.08	1.14	40.77	41.94	94.51	2.08	81.65
4.	Number of leaves per plant	3.69 ± 0.23	2.00 – 4.87	0.62	0.78	21.34	23.87	79.95	1.45	39.31
5.	Leaf length (cm)	17.24 ± 0.64	9.47 – 25.26	26.59	27.80	29.90	30.58	95.62	10.39	60.23
6.	Leaf breadth (cm)	14.89 ± 0.71	8.10 – 21.53	16.94	18.47	27.64	28.86	91.72	8.12	54.52
7.	Leaf thickness (mm)	0.50 ± 0.01	0.46 – 0.53	0.01	0.01	2.95	5.22	32.00	0.02	3.44
8.	Petiole length (cm)	12.11 ± 0.35	6.97– 20.67	19.65	20.02	36.59	36.94	98.14	9.05	74.67
9.	Petiole girth (cm)	2.46 ± 0.11	1.40 – 4.09	0.60	0.64	31.55	32.49	94.25	1.55	63.09
10.	Leaf area (cm^2)	202.95 ± 1.70	64.84 – 407.88	17913.30	19820.09	31.29	32.92	90.38	262.11	61.29
11.	Leaf area index	0.280 ± 0.003	0.08 – 0.73	0.06	0.06	40.48	41.75	94.02	0.47	80.86

GV: Genotypic variance
GCV: Genotypic coefficient of variance
h^2: Heritability (broad sense)
GA: Genetic advance
PV: Phenotypic variance
PCV: Phenotypic coefficient of variance
GAM: Genetic advance as per cent of mean

Table 2: Estimates of mean, range and genetic components of variation for yield and quality parameters in twenty colocasia genotypes.

Characters	Mean±S.Em.	Range	GV	PV	GCV (%)	PCV (%)	h^2 (%)	GA	GAM (%)
Corm length (cm)	12.67 ± 0.64	7.68 – 28.34	18.34	19.58	33.81	34.94	93.64	8.54	67.39
Corm width (cm)	6.73 ± 0.36	4.91 – 8.79	0.81	1.19	13.38	16.21	68.10	1.53	22.74
Cormel length (cm)	5.66± 0.30	4.39 – 14.85	4.91	5.18	39.13	40.19	94.79	4.44	78.47
Cormel width (cm)	2.62± 0.14	2.13 – 3.29	0.05	0.10	8.20	12.25	44.82	0.30	11.31
Corm weight (kg)	1.57 ± 0.09	0.55 – 4.31	0.97	0.99	62.72	63.42	97.81	2.01	127.78
Cormel weight (kg)	1.89 ± 0.08	0.79 – 3.59	0.53	0.55	38.41	39.05	96.77	1.47	77.84
Number of corms per plant	2.16 ± 0.11	1.20 – 3.60	0.42	0.46	29.96	31.31	91.56	1.27	59.05
Number of cormels per plant	26.25 ± 1.03	6.97 – 53.97	187.70	190.90	52.20	52.64	98.33	27.99	106.62
Herbage yield per plant (g)	52.29 ± 2.75	32.50 – 95.32	315.22	337.91	33.96	35.16	93.29	35.33	67.56
Corm yield per plant (g)	323.92 ±11.05	107.00 – 891.33	42165.59	42532.05	63.39	63.67	99.14	421.18	130.03
Cormel yield per plant (g)	378.58± 12.04	177.33– 731.67	20758.36	21193.45	38.06	38.45	97.95	293.74	77.59
Tuber yield per plant (g)	702.55 ± 40.60	284.33 – 1149.00	61745.70	66691.31	35.37	36.76	92.58	492.54	70.11
Tuber yield per plot (kg)	6.74 ± 0.23	2.83 – 10.87	6.68	6.84	38.36	38.81	97.69	5.26	78.10
Estimated tuber yield (t/ha)	22.46 ± 0.87	9.42 – 36.23	74.08	76.34	38.33	38.91	97.04	17.47	77.77
Starch content (%)	62.52 ± 3.97	46.80 – 77.90	97.10	144.49	15.76	19.23	67.20	16.64	26.62
Protein content (%)	9.21 ± 0.67	7.32 – 11.68	1.25	2.60	12.12	17.49	48.04	1.60	17.31
Dry matter content (%)	31.84 ± 1.34	23.00 – 46.00	24.04	29.46	15.40	17.05	81.61	9.13	28.66
Fiber content (%)	2.94 ± 0.13	1.34 – 5.00	1.12	1.17	35.96	36.82	95.38	2.12	72.34
TSS (°B)	3.43 ± 0.16	1.30 – 5.90	1.15	1.23	31.23	32.27	93.68	2.14	62.27
Total sugars (%)	4.42 ± 0.22	2.08 – 5.75	0.55	0.70	16.71	18.85	78.64	1.35	30.53
Reducing sugars (%)	2.91 ± 0.14	1.45 – 3.90	0.43	0.48	22.44	23.93	87.95	1.26	43.36
Non reducing sugars (%)	1.52 ± 0.06	0.21 – 2.50	0.42	0.43	42.48	43.12	97.05	1.31	86.21

GV: Genotypic variance
GCV: Genotypic coefficient of variance
h^2: Heritability (broad sense)
GA: Genetic advance
PV: Phenotypic variance
PCV: Phenotypic coefficient of variance
GAM: Genetic advance as per cent of mean

Table 3: Estimates of phenotypic and genotypic correlation coefficients for 11 characters among growth and yield parameters in twenty colocasia genotypes

Traits	Type of correlation	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}
X_1	P	1.000	0.881**	0.832**	0.904**	0.670**	0.374*	0.475**	0.297*	0.405*	0.381*	0.502**
	G	1.000	0.934**	0.920**	0.977**	0.718**	0.393*	0.512**	0.323*	0.421**	0.395*	0.536**
X_2	P		1.000	0.875**	0.923**	0.618**	0.433**	0.602**	0.384*	0.559**	0.442**	0.643**
	G		1.000	0.931**	0.986**	0.650**	0.444**	0.626**	0.399*	0.576**	0.451**	0.684**
X_3	P			1.000	0.874**	0.697**	0.347*	0.516**	0.280*	0.557**	0.370*	0.599**
	G			1.000	0.958**	0.736**	0.369*	0.540**	0.294*	0.586**	0.382*	0.654**
X_4	P				1.000	0.697**	0.385*	0.583**	0.322*	0.533**	0.381*	0.586**

	G				1.000	0.724**	0.410*	0.620**	0.346*	0.558**	0.407*	0.649**
X_5	P					1.000	0.385*	0.368*	0.282*	0.508**	0.363*	0.560**
	G					1.000	0.397*	0.393*	0.287*	0.517**	0.372*	0.598**
X_6	P						1.000	0.677**	0.754**	0.179	0.975**	0.679**
	G						1.000	0.707**	0.769**	0.185	0.990**	0.697**
X_7	P							1.000	0.443**	0.355*	0.660**	0.620**
	G							1.000	0.456**	0.369*	0.687**	0.665**
X_8	P								1.000	0.082	0.751**	0.476**
	G								1.000	0.079	0.764**	0.495**
X_9	P									1.000	0.168	0.813**
	G									1.000	0.176	0.840**
X_{10}	P										1.000	0.682**
	G										1.000	0.697**
X_{11}	P											1.000
	G											1.000

Critical r_p value 5% - 0.254 significant at p=0.05
Critical r_p value 1% - 0.330 significant at p=0.01
X_1 – Plant height (cm) @ 120 DAP
X_2 – Number of leaves per plant @ 120 DAP
X_3 – Leaf length (cm) @ 120 DAP
X_4 – Petiole length (cm) @ 120 DAP
X_5 –Leaf area (cm^2) @ 120 DAP
X_6 – Cormel weight ((kg)
X_7 – Number of corms per plant
X_8 – Number of cormels per plant
X_9 – Corm yield per plant (g)
X_{10} – Cormel yield per plant (g)
X_{11} – Tuber yield per plant (g)

Path coefficient analysis

Path coefficient analysis which is developed by Wright (1921) [29] is a standardized partial regression analysis which specifies the relative importance and measures the direct influence of one variable upon another through the dividing of the correlation coefficient into direct and indirect effects (Dewey and Lu, 1959) [7]. In agriculture path analysis can be used to help plant breeders for identification of traits that are useful as selection criteria to improve crop yield. Results of path analysis at both genotypic and phenotypic level revealed that the traits like plant height, number of leaves per plant, leaf length, corm yield per plant and cormel yield per plant had positive direct effect on tuber yield per plant (Table 4). Thus, the higher magnitude of the positive direct effect of these traits explains the higher values of association between these traits and tuber yield per plant. Therefore, direct selection for these traits would reward for improvement of yield. Similar results were reported by Devi *et al.* (2019) [6], Paul and Bari (2015) [16], Rao *et al.* (2017) [18], Singh and Yadav (2018) [22].

Table 4: Direct and indirect effects of various characters on tuber yield per plant in twenty colocasia genotypes at phenotypic and genotypic level

Traits	Type of Path Analysis	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1	P	0.0485	0.0427	0.0404	0.0439	0.0325	0.0181	0.0230	0.0144	0.0197	0.0185
	G	0.1344	0.1256	0.1237	0.1313	0.0965	0.0529	0.0688	0.0433	0.0566	0.0531
X_2	P	0.0025	0.0029	0.0025	0.0027	0.0018	0.0012	0.0017	0.0011	0.0016	0.0013
	G	0.1426	0.1526	0.1421	0.1504	0.0992	0.0677	0.0955	0.0609	0.0878	0.0687
X_3	P	0.0011	0.0012	0.0014	0.0012	0.0009	0.0005	0.0007	0.0004	0.0008	0.0005
	G	0.0476	0.0482	0.0517	0.0495	0.0380	0.0191	0.0279	0.0152	0.0303	0.0197
X_4	P	-0.0513	-0.0524	-0.0496	-0.0568	-0.0396	-0.0218	-0.0331	-0.0183	-0.0303	-0.0217
	G	-0.3581	-0.3614	-0.3512	-0.3667	-0.2656	-0.1504	-0.2274	-0.1268	-0.2045	-0.1491
X_5	P	-0.0100	-0.0092	-0.0104	-0.0104	-0.0149	-0.0058	-0.0055	-0.0042	-0.0076	-0.0054
	G	0.0203	0.0184	0.0208	0.0205	0.0282	0.0112	0.0111	0.0081	0.0146	0.0105
X_6	P	0.0242	0.0281	0.0225	0.0249	0.0250	0.0648	0.0439	0.0489	0.0116	0.0632
	G	-0.0071	-0.0080	-0.0067	-0.0074	-0.0072	-0.0181	-0.0128	-0.0139	-0.0033	-0.0179
X_7	P	-0.0030	-0.0038	-0.0032	-0.0037	-0.0023	-0.0043	-0.0063	-0.0028	-0.0022	-0.0042
	G	0.0293	0.0358	0.0309	0.0355	0.0225	0.0404	0.0572	0.0261	0.0211	0.0393
X_8	P	-0.0027	-0.0036	-0.0026	-0.0030	-0.0026	-0.0070	-0.0041	-0.0093	-0.0008	-0.0069
	G	0.0064	0.0079	0.0058	0.0068	0.0057	0.0152	0.0090	0.0198	0.0016	0.0151
X_9	P	0.2975	0.4104	0.4084	0.3914	0.3730	0.1317	0.2606	0.0598	0.7340	0.1233
	G	0.3129	0.4277	0.4355	0.4144	0.3845	0.1374	0.2739	0.0592	0.7431	0.1308
X_{10}	P	0.1956	0.2269	0.1900	0.1958	0.1862	0.5009	0.3390	0.3857	0.0862	0.5135
	G	0.2081	0.2374	0.2012	0.2143	0.1959	0.5216	0.3618	0.4025	0.0928	0.5270
X_{11}	P	0.502**	0.643**	0.599**	0.586**	0.560**	0.679**	0.620**	0.476**	0.813**	0.682**
	G	0.536**	0.684**	0.654**	0.649**	0.598**	0.697**	0.665**	0.495**	0.840**	0.697**

Diagonal values indicate direct effect
Residual effect=0.179
X_1 – Plant height (cm) @ 120 DAP
X_2 – Number of leaves per plant @ 120 DAP
X_3 – Leaf length (cm) @ 120 DAP
X_4 – Petiole length (cm) @ 120 DAP
X_5 – Leaf area (cm^2) @ 120 DAP
X_6 – Cormel weight ((kg)
X_7 – Number of corms per plant
X_8 – Number of cormels per plant
X_9 – Corm yield per plant (g)
X_{10} – Cormel yield per plant (g)
X_{11} – Tuber yield per plant (g)

Conclusion

In the present investigation, high values of GCV and PCV were observed for parameters like, plant height, diameter of stem, number of leaves per plant, leaf length, leaf breadth,

petiole length, petiole girth, leaf area, leaf area index, corm length, cormel length, corm weight, cormel weight, number of corms per plant, number of cormels per plant, herbage yield per plant, corm yield per plant, cormel yield per plant, tuber yield per plant, tuber yield per plot, estimated tuber yield, fiber content, TSS, reducing sugars and non-reducing sugars indicating the presence of greater variability for these traits and these can be further improved through direct selection. Estimates of high heritability coupled with high genetic advance as per cent over mean recorded for all the traits except leaf thickness, cormel width and protein content suggesting that these characters can be improved through direct selection due to predominance additive gene action.
Correlation studies revealed that tuber yield per plant exhibited a highly significant and positive correlation with the plant height, number of leaves per plant, leaf length, petiole length, leaf area, cormel weight, number of corms per plant, number of cormels per plant, corm yield per plant, cormel yield per plant both at genotypic and phenotypic level. Path coefficient analysis of different characters contributing towards tuber yield per plant indicated that plant height, number of leaves per plant, leaf length, corm yield per plant and cormel yield per plant exhibited positive direct effect both at genotypic and phenotypic level which indicating that direct selection based on these attributes can be used in developing high yielding varieties.

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