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Study of the relationship between dependent and independent yield and its traits in colocasia (*Colocasia esculenta* var. *antiquoroum* (L.) Schott)

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Abstract
Analyzed of the relationship between dependent and independent variables of yield with their associated traits in colocasia (*Colocasia esculenta* var. *antiquoroum* (L.) Schott) genotypes were investigated in experimentations years conducted at three locations. The experiment was laid out as randomized complete block design with three replications of all the locations. Data were collected on the growth and yield attribute characters of colocasia. The associations of the attributes measured in both the locations were studied to estimate the stepwise multiple regression. Considering stepwise multiple regression simultaneously as the best estimators of the amount of advance expected from selection, plant height, leaf area index, number of cormels plant^{-1}, cormels weight, cormels yield plant^{-1} and corm yield plant^{-1} gave the highest values in each of the locations. This shows that a satisfactory selection program for improvement of these genotypes through these traits is possible at each specific location. Stepwise multiple regression analysis revealed number of cormels plant^{-1}, cormel weight and corm weight as the biggest determinants of corms and cormels yield ha^{-1} of colocasia, both contributing about 85%, 82% and 78% at different locations of the total variation in yield. This suggests that these three characters are important selection indices for colocasia yield improvement.

Keywords: Yield, association, genotypes.

Introduction
Colocasia (*Colocasia esculenta* var. *antiquorum* L. Schott) also known as '*Taro*' is one of the oldest known tuber crop and has been grown for more than 10,000 years ago in Tropical Asia (Lebot, 2009) [9]. It is a tropical tuber crop belongs to the monocotyledonous family *Araceae* of the order *Arales* whose members are known as aroids (Henry, 2001) [8]. *Araceae* includes about 100 genera and 1500 widely distributed species. It has been probably originated from the humid tropical region between India and Indonesia (Matthews, 2004) and has been grown in the South Pacific for hundreds of years (FAO, 1992) [6]. Taro grows wild in tropical Asia, extending as far as east as New Guinea region near Indonesia and possibly Northern Australia. Taro serves as staple source of diet for people around the world and it is the fourteenth most consumed vegetable worldwide (Rao *et al.*, 2010) [13]. Globally taro is cultivated in an area of around 1.30 m ha with an annual production of 9.98 mt and average yield of 7.68 t/ha (FAOSTAT, 2016) [7].

In India, the major taro growing states are Manipur, Assam, Nagaland, Odissa, Meghalaya, Gujarat, Maharashtra, Kerala, Andhra Pradesh, Tamil Nadu, West Bengal, Uttar Pradesh, Chhattisgarh and Bihar. The area under colocasia in Chhattisgarh is about 7815 hectares with total production of 110260 metric tonnes. The area (819 ha) and highest production (12700 metric tonnes) is found in Kabirdham district followed by Kondagaon district with an area of 819 hectares and production of 11541 metric tonnes, respectively (Anonymous, 2019) [1].

To have a good choice of characters for selection of desirable genotypes under planned breeding program for higher yield, the knowledge of nature and magnitude of variation existing in available breeding materials, the association of component characters with yield and their exact contribution through direct and indirect effects are of crucial importance. Yield is a complex quantitative character and is the resultant of various component characters associated with each other. Therefore, for understanding the effect of the components on yield, it is essential to know the association of different characters among themselves and with that of yield (Mukharjee *et al*., 2016) [11]. Dewey *et al.* (1959) [4] applied this method for the first time to plants in order to analyze the inter-correlation in a cause and effect system in crested wheat grass. The component characters are interrelated among themselves and also influence the yield. Correlation measures the inter relationship between two or more variables.

Estimation of association among the yield contributing variables is necessary to understand the direction of selection and to maximize yield in shortest period of time. Genetic correlation indicates the relative importance of character (s) on which greater emphasis should be made in selection for yield. However, as the number of variables in the correlation study increases the direct and indirect association between yield and particular component characters become complex. Multiple regression analysis which determines the cause and effects relationship is therefore has immense importance in splitting the association in to its effects contributing to yield. Therefore, the present study was undertaken to gather helpful information on trait association of yield components in 24 genotypes of colocasia.

Materials and Methods

The experiments were conducted at SG, College of Agriculture and Research Station, IGKV, Instructional cum Research Farm, Kumhrawand, Jagdalpur, Bastar, Chhattisgarh (Ll), Krishi Vighyan Kendra, IGKV, Kanker (L2) and on Farmer's field at Village - Karli, Distt. Dantewada (L3) during the summer season from 1st year February to August 2018 and 2nd year during February to August 2019.

Table 1: Locations, sea level, rainfall and soil type of the testing sites

Locations	Latitude	Longitude	Altitude A.S.L. (fit)	Annual mean rainfall (mm)	Soil texture
Jagdalpur	$19^0$05' N	82^o 02' E	1811	1386	Silty clay
Kanker	$20^0$14' 42N	80^o 30'30 E	1273	1324	Sandy loam
Dantewada	$18^0$58'39 N	81^o 22'53	1152	1392	Sandy loam

Twenty four indigenous genotypes of colocasia were collected from twenty seven districts of Chhattisgarh (latitude 21.2787 °N and longitude 81.8661° E) *viz*., Dantwada, Bastar, Kondagaon, Naryanpur, Kanker, Gariyaband, Mahasmund, Bilashpur, Korba, Dhamtari, Rajnandgaon, Surguja, Jashpur, Korea and Balod during March 2017 to June 2018. The genotypes were grown under Bastar plateau (19.09073 °N 81.96186°E) condition. The collected indigenous genotypes have been listed in table with their brief description.

Table 2: Collection from indigenous genotypes of colocasia producing regions of C.G.

S. No.	Collection No. and Name	Place of Collection	S. No.	Collection No. and Name	Place of Collection
1.	IGCOL-PITH-17-1	Mahasamund	13.	IGCOL-CHLN-17-1	Bastar
2.	IGCOL-KOTA-17-1	Bilaspur	14.	IGCOL-MNDG-17-1	Kabirdham
3.	IGCOL-NGR-17-1	Dhamtari	15.	IGCOL-GB-17-1	Gariyaband
4.	IGCOL-SPL-17-1	Mahasamund	16.	IGCOL- PWND-17-2	Bastar
5.	IGCOL-PWD-17-1	Kanker	17.	IGCOL-BNR-17-1	Narayanpur
6.	IGCOL-PWND-17-1	Kanker	18.	IGCOL-KDKN-17-1	Bastar
7.	IGCOL-KS-10-1	Kabirdham	19.	IGCOL-MUNG-17-1	Mungeli
8.	IGCOL-KS-13-2	Kabirdham	20.	White Gauriya (S.C.)	Check variety
9.	IGCOL-BL-12-1	Balrampur	21.	IGCOL-DK-17-1	Kanker
10.	IGCOL-JS-12-1	Jashpur	22.	IGCOL-CHHTD-18-1	Nayaranpur
11.	IGCOL-BDL-17-1	Kabirdham	23.	IGCOL-CHMD-18-1	Bastar
12.	IGCOL-PKJ-17-1	Kanker	24.	IGCOL-LHDD-18-1	Bastar

The experiment was laid out as a Randomized Complete Block Design with three replications at both locations. Each plot measured 3 m by 3 m, consisting of 5 rows with plant spacing of 60 cm by 30 cm. For the Study of the relationship between dependent and independent yield multiple regression model were applied.

Results and Discussions

The regression coefficients with their probability value and accuracy of regression model are measured using R^2 value of different locations *viz*., Jagdalpur, Kanker, and Dantewada district have been presented in Table 3. Also, there is only marginal difference in goodness of fit statistics (R^2) among these three district.The value of R^2 is closer to one than it is able to explain most of the variations on the prediction model (Nancy, 2010) [12]. Goodness of fit (R^2) values indicated that the multiple regression technique fitted well to the data of corms and cormels yield. In this analysis, two or more yield attributing character (variables) is used to estimate the values of a colocasia genotypes yield.

Jagdalpur district

The regression model corms and cormels yield the following equation while regressed to the fifteen explanatory variables against corms and cormels yield;

$$\begin{aligned} Y = 78.02 + 0.37\,X_1 + 8.98\,X_2 - 1.32\,X_3 + 15.79\,X_4 \\ + 13.49^*\,X_5 + 4.52^*\,X_6 + 0.41\,X_7 \\ + 25.79\,X_8 + 3.98^*\,X_9 + 0.43^*X_{10} \\ - 1.61\,X_{11} + 0.14\,X_{12} + 8.70\,X_{13} \\ + 0.25\,^*X_{14} - 0.27\,X_{15} \end{aligned}$$

The intercept (78.02) in a multiple regression model is the mean for the response when all of the independent variables i.e. plant height, number of suckers, petiole length, girth of Pseudo stem, leaf area index, number of cornel plant, cormel length, cormel girth, cormel weight, cormels yield plant^{-1}, dry matter of cormel, corm length, corm girth, corm yield plant^{-1}, dry matter of corms, take on the value 0. The coefficient of the variable is interpreted as the change in the response based on a 1 unit change in corresponding independent variables, keeping all other variables hold constant.

The regression line explaining about 85 percent (R^2 = 0.85) variations in corms and cormels yield by the independent variable. The yield attributing characters of corms and cormels yield i.e. Leaf area index (0.04), No. of cormels plant^{-1} (0.05), cormel weight (0.03), cormels yield per plant (0.03) and corm yield plant^{-1} (0.03) are significant with their p-value (<0.05). The higher p-value (>0.05) indicate the impact of these predictor variables *i. e.* plant height (0.88), number of suckers (0.27), petiole length (0.67), girth of Pseudo stem (0.43), cormel length (0.96), cormel girth (0.25), dry matter of cormel (0.81), corm length (0.98), corm girth (0.73), dry matter per cent of corm (0.90) on corms and cormels yield were not statistically significant.

This means the model had satisfactory predictive ability due to the inclusion of some important explanatory variables in the equation. Analyzing the equation, it could be said that the critical yield attributing variable explaining the most variations in the yield of corms and cormels were leaf area index, number of cormels plant^{-1}, cormel weight, cormels yield plant^{-1} and corm yield plant^{-1} were turned out to be important.

Kanker district

The regression model corms and cormels yield the following equation while regressed to the fifteen explanatory variables against corms and cormels yield;

$$Y = 71.18 + 0.27\,X_1 + 0.25\,X_2 - 0.40\,X_3 - 0.24\,X_4 + 1.30\,^{*}X_5 + 0.59^{*}\,X_6 - 0.93\,X_7 + 6.70\,X_8 + 0.14^{**}\,X_9 + 0.54\,^{**}\,X_{10} - 0.93\,X_{11} + 2.16^{*}\,X_{12} + 1.68\,X_{13} + 0.67\,^{**}X_{14} - 0.47\,X_{15}$$

The intercept (71.18) in a multiple regression model is the mean for the response when all of the independent variables *i.e.* plant height, number of suckers, petiole length, girth of Pseudo stem, leaf area index, number of cornels plant^{-1}, cormel length, cormel girth, cormel weight, cormels yield plant^{-1}, dry matter per cent of cormel, corm length, corm girth, corms yield plant^{-1}, dry matter per cent of corm, take on the value 0. The coefficient of the variable is interpreted as the change in the response based on a 1 unit change in corresponding independent variables, keeping all other variables hold constant.

The regression line explaining about 82 percent ($R^2 = 0.82$) variations in corms and cormels yield by the independent variable. The yield attributing characters of corms and cormels yield *i.e.* leaf area index (0.05), number of cormels plant^{-1} (0.03), cormel weight (0.01), cormels yield plant^{-1} (0.01), corm length (0.04) and corm yield plant^{-1} (0.01) are significant with their p-value (<0.05). The higher p-value (>0.05) indicate the impact of these predictor variables *i.e.* plant height (0.52), number of suckers (0.86), petiole length (0.38), girth of Pseudo stem (0.92), cormel length (0.51), cormel girth (0.34), dry matter of cormel (0.29), corm girth (0.55), dry matter per cent of corm (0.22) on corms and cormels yield were not statistically significant.

This means the model had satisfactory predictive ability due to the inclusion of some important explanatory variables in the equation. Analyzing the equation, it could be said that the critical yield attributing variable explaining the most variations in the yield of corms and cormels were leaf area index, number of Cormels plant^{-1}, cormel weight, cormels yield plant^{-1} corm length, and corm yield plant^{-1} were turned out to be important.

Dantewada district

The regression model corms and cormels yield the following equation while regressed to the fifteen explanatory variables against corms and cormels yield;

$$Y = 68.18 + 0.17\,X_1 - 0.08\,X_2 - 0.29\,X_3 + 11.66\,X_4 + 6.13\,^{*}X_5 + 1.94^{*}\,X_6 + 0.66\,X_7 - 11.83\,X_8 + 1.16\,^{*}X_9 + 0.52^{**}\,X_{10} - 3.30\,^{*}X_{11} + 0.27\,X_{12} - 11.15\,X_{13} + 0.53\,^{**}X_{14} - 1.35\,^{*}X_{15}$$

The intercept (68.18) in a multiple regression model is the mean for the response when all of the independent variables i.e. plant height, number of suckers plant^{-1}, petiole length, girth of Pseudo stem, leaf area index, number of cornels plant^{-1}, cormel length, cormel girth, cormel weight, cormels yield plant^{-1}, dry matter per cent of cormel, corm length, corm girth, corm yield plant^{-1}, dry matter per cent of corm, take on the value 0. The coefficient of the variable is interpreted as the change in the response based on a 1 unit change in corresponding independent variables, keeping all other variables hold constant.

The regression line explaining about 78 percent ($R^2 = 0.78$) variations in corms and cormels yield by the independent variable. The yield attributing characters of corms and cormels yield *i.e.* leaf area index (0.05), number of cormels plant^{-1} (0.04), cormel weight (0.05), cormels yield plant^{-1} (0.01), dry matter per cent of cormel (0.03), corm yield plant^{-1} (0.01) and dry matter percent of corm (0.04) are significant with their p-value (<0.05). The higher p-value (>0.05) indicate the impact of these predictor variables *i.e.* plant height (0.60), number of suckers (0.96), petiole length (0.48), girth of pseudo stem (0.06), cormel length (0.80), cormel girth (0.12), corm length (0.85), and corm girth (0.06), on corms and cormels yield were not statistically significant.

This means the model had satisfactory predictive ability due to the inclusion of some important explanatory variables in the equation. Analyzing the equation, it could be said that the critical yield attributing variable explaining the most variations in the yield of corms and cormels were leaf area index, number of cormels plant^{-1}, cormel weight, cormels yield plant^{-1}dry matter percent of cormel, corm yield plant^{-1} and dry matter percent of corm were turned out to be important.

The result showed that six attributes, namely, leaf area index, number of cormels plant^{-1}, cormel weight, cormels yield plant^{-1} corm length, and corm yield plant^{-1} were largest contributions to yield at all of three locations Jagdalpur, Kanker and Dantewada except dry matter percent of corm at Dantewada. These six attributes significantly predicted and explained approximately 81.67% (85%, 82% and 78% of three locations respectively) of the yield variation observed. Cormels yield plant^{-1} was the largest single contributor and accounted 49.67% of the total variation in yield followed by corm yield plant^{-1} accounted for 48%. Cormels yield plant^{-1} as the largest contributor to colocasia yield is therefore, an important indicator for estimating and improving colocasia yield through selection of this trait would have good impact on colocasia yield. The above finding of multiple regression studies are also in agreement with the finding of Eze and Nwofia (2016) [5] reported corms and cormels yield quintal ha^{-1} had the strongest positive and highest contribution to cormel weight (g), number of cormels plant^{-1} and number of leaves, Darabad (2014) [3] for plant height, number of main stem, dry matter percentage and number of tuber plant^{-1} had recorded the highest contribution and accounted 99% justification of existing changes in tuber yield by the variable mentioned, Zakerhamidi and Hassanpanah (2014) [14] reported that tuber yield exhibited variables having significant impact with plant height and main stem plant^{-1} and Atif *et al.* (2012) [2] reported for high grain yield exhibited best performance of traits for rice genotypes.

Conclusions

This investigation indicates the presence of inter relationship between the genotypes for the different characters under consideration and suggests straight selection for leaf area index, number of cormels plant^{-1}, cormel weight, cormels yield plant^{-1} and corm yield plant^{-1} as a means of improving this crop. Stepwise multiple regression analysis exhibit number of cormels plant^{-1} and cormel weight as the most important contributors to colocasia yield. They should therefore be considered as important selection indices for taro improvement aimed at developing high yielding varieties/hybrids in these locations.

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