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Correlation studies and path analysis on root traits contributing to nitrogen use efficiency in cassava genotypes

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Abstract
Twenty genotypes of cassava from ICAR-CTCRI were used to study the relation of root traits with nitrogen use efficiency following the Randomized block design (RBD) experimental set up. Association studies were carried out for 9 characters which covers, number of nodal roots, number of basal roots, number of storage roots, number of adventitious roots, length of roots, weight of storage roots, weight of basal and nodal roots, nitrogen use efficiency and tuber yield per plant. Significant positive correlation was observed for characters, number of basal roots, weight of basal and nodal roots, length of roots and number of adventitious roots with nitrogen use efficiency. Path analysis revealed that the characters, weight of basal and nodal roots, weight of storage roots, number of adventitious roots, length of roots and number of nodal roots had a direct effect on dependent character, nitrogen use efficiency.

Keywords: Correlation, path analysis, nitrogen use efficiency, cassava, root traits

1. Introduction

Cassava (*Manihot esculenta* Crantz) belongs to the family Euphorbiaceae and is the fourth most important food crop after rice, wheat, and maize worldwide. It is the staple food for over 500 million people in tropical areas and is mostly cultivated by resource-poor, marginal farmers for their livelihood (Rabbi *et al*., 2017) [9]. The crop is grown for its starchy tuberous roots, a major source of carbohydrates, and is commonly used as a food, feed, and even as industrial processing material. Cassava is a reliable source of abundant energy and can be bred to enhance its nutritional quality, such as micronutrients and proteins (CIAT, 2004) [2]. Plants require various elements for carrying out their physiological and biochemical processes. Out of the 17 key nutritional elements required for plant growth and development, Nitrogen, Phosphorus, and Potassium play the most significant role. Therefore, low N and/or P availability in soils significantly limits crop growth and production, making them high-priority objectives for increasing crop nutrient efficiency. The ability of plants to absorb mineral nutrients from soils is greatly influenced by root exploration (Li *et al.*, 2016) [6]. Nutrient use efficiency (NUE) itself is a root-related trait that reflects the efficiency of root structure and its ability in capturing the applied nutrients and those already present in the soil. Having an adequate sink to store the nutrients taken up from the soil also contributes to efficiency. Thus, it is important to understand how the root traits contribute to classifying a genotype as a nutrient-efficient/ less efficient one. Identification of the genotypes with high nutrient efficiency helps us to understand the differences in nutrient uptake and response to fertilizer application and the dynamics of nutrients in the soil (Melvin *et al.*, 2002).

2. Materials and methods

Twenty genotypes of cassava including pre-released and released varieties from ICAR-CTCRI were used to study the relation of root traits with nitrogen use efficiency. The design followed was a Randomized block design (RBD) with three replications at a spacing of 90x90 cm and destructive sampling was followed to study the different root-related traits. The different observations taken include number of nodal roots, number of basal roots, number of storage roots, number of adventitious roots, length of roots, weight of storage roots, weight of basal and nodal roots, nitrogen use efficiency and tuber yield per plant. The setts (cut stems) were used as the planting materials and the roots that arise from the nodes of the sett were counted as nodal roots, while those from the base of the sett were taken as the basal roots. The root length was recorded from the basal roots using a ruler.

The total number of basal and nodal roots constitutes the number of adventitious roots (Kengkann *et al.* 2019) [5]. Nitrogen use efficiency was calculated by dividing biological yield (Kg) with N uptake in Kg per plant as suggested by Soon (1992) [10].

Table 1: Genotypic correlation values of characters taken for the study

	Number of nodal roots	Number of storage roots	Number of basal roots	Number of adventitious roots	Length of roots	Weight of storage roots	Weight of basal and nodal roots	N use efficiency	Tuber yield per plant
Number of nodal roots	1	-0.179	0.297*	0.685**	-0.263*	0.088	0.043	0.111	-0.017
Number of storage roots	-0.179	1	-0.091	-0.152	0.487**	0.679**	0.392*	-0.136	0.574**
Number of basal roots	0.297*	-0.091	1	0.899**	0.581**	-0.002	0.635**	0.354*	0.139
Number of adventitious roots	0.685**	-0.152	0.899**	1	0.323*	0.039	0.504**	0.32*	0.098
Length of roots	-0.263*	0.487**	0.581**	0.323*	1	0.205	0.705**	0.193*	0.38*
Weight of storage roots	0.088	0.679**	-0.002	0.039	0.205	1	0.167	0.033	0.196
Weight of basal and nodal roots	0.043	0.392*	0.635**	0.504**	0.705**	0.167	1	0.351*	-0.006
N use efficiency	0.111	-0.136	0.354*	0.32*	0.193*	0.033	0.351*	1	0.175
Tuber yield per plant	-0.017	0.574**	0.139	0.098	0.38*	0.196	-0.006	0.175	1

** - Significant at 1% level of probability, * - significant at 5% level of probability

Table 2: Path coefficients indicating the direct (diagonal values) and indirect effects of characters on NUE

	Number of nodal roots	Number of storage roots	Number of basal roots	Number of adventitious roots	Length of roots	Weight of storage roots	Weight of basal and nodal roots	Genotypic correlation
Number of nodal roots	0.006	0.126	-0.055	0.023	-0.046	0.034	0.023	0.111
Number of storage roots	-0.001	-0.703	0.017	-0.005	0.085	0.26	0.212	-0.136
Number of basal roots	0.002	0.064	-0.185	0.03	0.101	-0.001	0.343	0.354
Number of adventitious roots	0.004	0.107	-0.166	0.33	0.056	0.015	0.272	0.32
Length of roots	-0.002	-0.342	-0.108	0.011	0.174	0.079	0.381	0.193
Weight of storage roots	0.001	-0.477	0	0.001	0.036	0.383	0.09	0.033
Weight of basal and nodal roots	0	-0.275	-0.117	0.017	0.123	0.064	0.54	0.351

In the present investigation, attempt has been made to study the interdependence between the characters *viz*., number of nodal roots, number of basal roots, number of storage roots, number of adventitious roots, length of roots, weight of storage roots, weight of basal and nodal roots, nitrogen use efficiency and tuber yield per plant using correlation studies. Path analysis was performed to find out the direct and indirect effect of the root traits on the dependent character nitrogen use efficiency.

3. Results and discussion

Correlation studies play a vital role in plant breeding as it guides the breeder in understanding the relative importance of different plant characters, thereby helping in effective selection. It can be either negative or positive based on the association between the characters under study. Here the genotypic and phenotypic correlation coefficients were calculated for the nine characters and it was observed that their genotypic correlation coefficients were higher than their phenotypic coefficients, which shows the presence of a stronger genetic relationship between them. Nitrogen use efficiency showed a positive genotypic correlation with number of basal roots (0.354) followed by the weight of basal and nodal roots (0.35), length of roots (0.34) and number of adventitious roots (0.32), while tuber yield per plant has a positive correlation with number of storage roots (0.574) and length of roots (0.38). This signifies the importance of root length and number of basal roots in nitrogen use efficiency as earlier reported by Zhang *et al.* (2015) [11] based on their nutrient use efficiency studies in rice. An increase in the root length and lateral root branching has been reported to have a positive impact on the nitrogen use efficiency and thereby the overall yield in rice (Arai-Sanoh *et al*., 2014) [1]. Figueiredo *et al.* (2014) [3] found a close positive correlation between root length and nitrogen efficiency in the IAC 576-70 cultivar of cassava. Moreover, since the storage roots are the economical part of cassava, it contributes mostly to the yield of the plant. Nodal roots exhibited a significant positive correlation with number of adventitious roots (0.685) and number of basal roots (0.297) but has a negative correlation with the length of roots. Number of storage roots were found to be strongly correlated to the length of roots (0.487), weight of basal and nodal roots (0.392) and weight of the storage root (0.679). A negative correlation was observed between number of nodal roots and the length of roots (-0.263).

Path analysis helps in understanding the direct and indirect effect of the independent characters on a dependent character and usually, yield is taken as the dependent character. Since this study focuses on the effect of the root traits on nitrogen use efficiency, here NUE is taken as the dependent character and path analysis was carried out for analyzing the direct and indirect effect of the root traits on nitrogen use efficiency. Here, the weight of basal and nodal roots has the highest direct effect on nitrogen use efficiency (0.54) followed by the weight of storage roots (0.383), number of adventitious roots (0.33), length of roots (0.174) and number of nodal roots. This suggests that the direct selection of these characters will have an impact on the nitrogen use efficiency in cassava. A direct relation of the number of roots with nitrogen use efficiency was also reported by Oliveira *et al.* (2017) [8]. Izumi *et al.* (1999) [4] reported that the number and the length of adventitious roots have a positive direct effect on the absorption and nutrient use efficiency in cassava. The characters like number of storage roots and number of basal roots exhibited a significant negative effect on nitrogen use efficiency which implies that selection for these characters is ineffective.

4. Conclusion

It is concluded from the present investigation that a significant positive correlation was obtained for the four characters with the nitrogen use efficiency. From path analysis results, five characters showed direct effect on the dependent character, nitrogen use efficiency. These results indicate the significance of root traits towards the efficiency by which nutrients are being consumed by plants. Therefore, selection based on these root traits will be beneficial as it reflects the potential of root structure to capture the externally applied as well as the nutrient already existing in the soil.

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