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Correlation and path coefficient analysis in drumstick (*Moringa oleifera* L.)

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ABSTRACT

The experiment was conducted to analyze the genotypic and phenotypic correlations and path coefficients among various traits in drumstick (Moringa oleifera L.) using 37 genotypes at the Mudhipar farm of D.K.S. College of Agriculture and Research Station, Bhatapara, during 2021-22. The experiment followed a Randomized Block Design (RBD) with three replications. Observations were recorded for plant height, stem thickness, number of primary branches per plant, length of leaf rachis, number of leaves per rachis, leaf length, number of inflorescences per plant, number of flowers per inflorescence, number of pods per inflorescence, number of pods per plant, marketable pod length, pod girth, number of seeds per pod, marketable pod weight, and marketable pod yield per plant. The genotypic and phenotypic correlations were determined using Miller et al. (1958) methodology, while path coefficient analysis was employed to understand the direct and indirect effects of these traits on marketable pod yield. Results revealed that Marketable pod weight (g), Number of pods per plant and number of inflorescences per plant exhibited significant positive correlations with marketable pod yield. Path coefficient analysis indicated that the number of pods per plant had the highest positive direct effect on marketable pod yield, followed by marketable pod weight and number of seeds per pod. These findings suggest key traits for selection in breeding programs aimed at improving marketable pod yield in drumstick.

Key words: *Drumstick, Genotypic correlation, Medicinal, Path coefficient analysis and phenotypic correlation*

INTRODUCTION

Moringa oleifera L., commonly known as drumstick or the Miracle Tree, is a versatile and resilient deciduous tree belonging to the family Moringaceae. This remarkable tree thrives in both humid tropical and arid climates and can survive in poor soil conditions, showcasing its adaptability and hardiness (Morton, 1991). Pods length ranged from 26.70 to 59.47 cm (Tak *et al.,* 2015), flowers, and leaves of drumstick are integral components of the cuisine in southern, central, and eastern India, offering not only culinary diversity but also substantial nutritional benefits. Drumstick is renowned for its exceptional nutritional profile. It is reported to provide seven times more vitamin C than oranges, ten times more vitamin A than carrots, seventeen times more calcium than milk, nine times more protein than yogurt, fifteen times more potassium than bananas, and twenty-five times more iron than spinach (Gopalakrishnan *et al.*, 2016). These extraordinary nutritional benefits have garnered significant attention, making Moringa oleifera a focal point for both dietary and agricultural research. In this study, we aim to investigate the correlations among various horticulture traits of *Moringa oleifera*, along with path coefficient analysis, to understand the direct and indirect effects of these traits on yield and other important characteristics. By elucidating these relationships, we hope to contribute to the optimization of breeding strategies and cultivation practices for this nutritionally rich and horticulturally valuable crop.

MATERIAL AND METHODS

The experiment was conducted using a Randomized Block Design (RBD) with three replications, encompassing 37 genotypes, at the Mudhipar farm of D.K.S. College of Agriculture and Research Station, Bhatapara, during 2021-22. The experimental material included 37 genotypes: BM-1, BM-2, BM-3, BM-4, BM-5, BM-6, BM-7, BM-8, BM-9, BM-10, BM-11, BM-12, BM-13, BM-14, BM-15, BM-16, BM-17, BM-18, BM-19, BM-20, BM-21, BM-22, BM-23, BM-24, BM-25, BM-26, BM-27, BM-28, BM-29, BM-30, BM-31, BM-32, BM-33, BM-34, BM-35, and BM-36, all of which were collected from Baloda

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Bazar, Bhatapara, and Bemetara districts under the Veg-10 RPF Project by the Department of Vegetable Science at DKS Mudhipar Farm, Bhatapara, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh). Standard horticultural practices were meticulously followed throughout the experiment.

Observations were recorded from five randomly selected plants for Plant height (m), Stem thickness (cm), Number of primary branches per plant, Length of leaf rachis (cm), Number of leaves per rachis, Leaf length (cm), Number of inflorescences per plant, Number of flowers per inflorescence, Number of pods per inflorescence, Number of pods per plant, Marketable pod length (cm), Pod girth (cm), Number of seeds per pod, Marketable Pod weight (g), Marketable pod yield per plant (kg). The Methodology suggested by Miller *et al.*(1958) has been used for the determination of the genotypic and phenotypic correlation.

Correlation and path coefficient analysis give an insight into the genetic variability present in population. Correlation coefficient analysis measure the mutual relationship between various plant characters and determines the component characters on which selection can be based for improvement in yield.The concept of path coefficient analysis has been proposed by Wright(1921) and used by DeweyandLu (1959) in plant breeding path co-efficient analysis technique was used to find outthe relative contribution of component characters directly on the main character, alsoquoted inSingh and Chaudhury (1985), using simple correlation values for the same.

RESULT AND DISCUSSION

The phenotypic (P) and genotypic (G) correlation coefficient were analyzed for sixteen characters of *Moringa* and the finding are presented in Table 1 and only significant correlations are explained:

Plant height (m)

Plant height (m) exhibited highly significant and positive correlations with various traits. Specifically, it showed strong correlations with stem thickness (cm) (0.486 and 0.528), number of primary branches per plant (0.319 and 0.358), number of inflorescences per plant (0.311 and 0.334), number of flowers per inflorescence (0.354 and 0.410), number of pods per plant (0.392 and 0.447), number of seeds per pod (0.358 and 0.653), marketable pod weight (g) (0.359 and 0.549), and marketable pod yield per plant (kg) (0.427 and 0.453) at both phenotypic and genotypic levels. Moreover, there was a highly significant positive correlation observed with marketable pod length (0.314) at the genotypic level. Additionally, significant positive correlations were found with marketable pod length (0.268) at the phenotypic level, as well as with the length of leaf rachis (0.242) and number of pods per inflorescence (0.210) at the genotypic level.

Stemthickness (cm)

Stemthickness (cm) showed highly significant and positive correlation with number of primary branches per plant (0.515 and 0.545),number of inflorescences per plant (0.392 and0.419), number of pods per plant (0.426 and 0.444),marketable pod length (cm) (0.364 and 0.438) marketable pod weight (g) (0.474 and 0.666) and marketable pod yield per plant (kg) (0.479 and 0.513) at bothphenotypic and genotypic levels, number of seeds per pod(0.614) atgenotypic level and significant positive correlation number of seeds per pod (0.290) at phenotypic level. It also showed significant positive correlation with number of flowers per inflorescence (0.221 and 0.246) at both phenotypic and genotypiclevels.

Number of primary branches per plant

The number of primary branches per plant exhibited a highly significant and positive correlation with several key parameters, both at phenotypic and genotypic levels. Specifically, it correlated positively with the number of inflorescences per plant (0.372 and 0.395), the number of pods per plant (0.327 and 0.344), marketable pod weight (0.311 and 0.439), and marketable pod yield per plant (0.361 and 0.383). Moreover, the number of seeds per pod showed a highly significant correlation at the genotypic level. Additionally, there was a significant positive correlation observed between the number of primary branches per plant and other traits. These include the number of flowers per inflorescence (0.201 and 0.221), marketable pod length (0.199 and 0.242) at both phenotypic and genotypic levels, length of leaf rachis (0.195) at the genotypic level, and the number of

Table 1: Correlation coefficient analysis (Phenotypic and genotypic) among marketable pod yield and its component

Characters		2	3	4	5	6	7	8	9	10	11	12	13	14
Plant height (m)	P	0.486**	0.319**	0.1863	0.1592	0.311**	0.354**	0.1692	0.392**	0.268*	-0.1203	0.358**	0.359**	0.427**
	G	0.528**	0.358**	0.242*	0.1718	0.334**	0.410**	0.210*	0.447**	0.314**	-0.1099	0.653**	0.549**	0.453**
Stem thickness (cm)	P		0.515**	0.0784	0.0054	0.392**	0.221*	0.1522	0.426**	0.364**	-0.0715	0.290*	0.474**	0.479**
	G		0.545**	0.0881	-0.0058	0.419**	0.246*	0.1732	0.444**	0.438**	-0.0679	0.614**	0.666**	0.513**
Number of primary branches per plant	P			0.1612	0.0567	0.372**	0.201*	0.0335	0.327**	0.199*	-0.0356	0.1762	0.311**	0.361**
	G			0.195*	0.1052	0.395**	0.221*	0.0462	0.344**	0.242*	-0.0834	0.363**	0.439**	0.383**
Length of leaf rachis	P				0.795**	0.438**	0.405**	0.435**	0.572**	0.545**	-0.0154	0.381**	0.469**	0.587**
	G				0.988**	0.507**	0.494**	0.518**	0.634**	0.674**	0.0003	0.787**	0.685**	0.656**
Leaf length (cm)	P					0.345**	0.344**	0.471**	0.445**	0.419**	0.0143	0.306*	0.381**	0.451**
	G					0.435**	0.435**	0.583**	0.541**	0.600**	-0.0074	0.720**	0.544**	0.549**
Number of inflorescences per plant	P						0.497**	0.445**	0.843**	0.601**	0.0239	0.439**	0.553**	0.827**
	G						0.559**	0.505**	0.900**	0.709**	-0.0085	0.784**	0.803**	0.889**
Number of flowers per inflorescence	P							0.485**	0.577**	0.550**	-0.0507	0.364**	0.453**	0.587**
	G							0.544**	0.654**	0.730**	0.0329	0.817**	0.673**	0.655**
Numberofpodsperinflorescence	P								0.600**	0.470**	0.0987	0.226*	0.383**	0.596**
	G								0.672**	0.672**	0.1353	0.620**	0.606**	0.662**
Number ofpods perplant	P									0.672**	0.0033	0.425**	0.614**	0.939**
	G									0.811**	0.0009	0.882**	0.890**	0.924**
Marketablepodlength (cm)	P										0.0289	0.570**	0.624**	0.736**
	G										0.1003	0.955**	0.980**	0.855**
Pod girth (cm)	P											0.0443	0.0558	-0.0079
	G											0.1084	-0.0893	0.0058
Numberof seedsper pod	P												0.569**	0.476**
	G												0.885**	0.842**
Marketable Podweight(g)	P													0.698**
	G													0.924**

Significantat 5%,Significant at1%,at bothP=Phenotypic;G=Genotypiclevels*

Table 2: Pathmatrix of Direct (diagonal) and indirect effects on marketable pod yield and its attribut e straits at genotypiclevel in Moringa

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13	Genotypic Correlation
1	-0.180	-0.095	-0.064	-0.044	-0.031	-0.060	-0.074	-0.038	-0.080	-0.057	0.020	-0.117	-0.099	0.453**
2	-0.051	-0.097	-0.053	-0.009	0.001	-0.041	-0.024	-0.017	-0.043	-0.043	0.007	-0.060	-0.065	0.513**
3	0.012	0.018	0.033	0.007	0.004	0.013	0.007	0.002	0.012	0.008	-0.003	0.012	0.015	0.383**
4	0.066	0.024	0.053	0.273	0.270	0.138	0.135	0.141	0.173	0.184	0.000	0.215	0.187	0.656**
5	-0.067	0.002	-0.041	-0.387	-0.392	-0.171	-0.171	-0.228	-0.212	-0.235	0.003	-0.282	-0.213	0.549**
6	-0.061	-0.077	-0.072	-0.093	-0.080	-0.183	-0.102	-0.092	-0.165	-0.130	0.002	-0.143	-0.147	0.889**
7	-0.027	-0.016	-0.015	-0.032	-0.029	-0.037	-0.066	-0.036	-0.043	-0.048	-0.002	-0.054	-0.044	0.655**
8	0.018	0.015	0.004	0.044	0.050	0.043	0.046	0.085	0.057	0.057	0.012	0.053	0.052	0.662**
9	0.423	0.420	0.325	0.599	0.511	0.850	0.618	0.634	0.945	0.767	0.001	0.833	0.841	0.924**
10	-0.140	-0.195	-0.108	-0.301	-0.268	-0.316	-0.326	-0.298	-0.362	-0.446	-0.045	-0.426	-0.438	0.855**
11	-0.003	-0.002	-0.002	0.000	0.000	0.000	0.001	0.004	0.000	0.003	0.027	0.003	-0.002	0.0058
12	0.198	0.187	0.110	0.239	0.219	0.238	0.248	0.188	0.268	0.290	0.033	0.304	0.406	0.842**
13	0.264	0.320	0.211	0.329	0.261	0.386	0.323	0.291	0.428	0.471	-0.043	0.642	0.480	0.924**

square = 0.3768 Residual effect =0.7894 (,**=Significant at 5% and1% levels, respectively)*

Boldvalues show direct and normal values showed indirect effects

1-Plant height (m)
2-Stem thickness (cm)
3-Number of primary branches per plant,
4-Length of leafrachis
5- Leaf length (cm)
6- Number of inflorescences per plant
7- Number of flowers per inflorescence
8- Number of pods per inflorescence
9- Number of pods per plant
10- Marketable pod length (cm)
11- Pod girth(cm)
12- Number of seeds perpod
13- Marketable Pod weight (g)
14- Marketable pod yield per plant (kg)

seeds per pod (0.363) at the phenotypic level. These findings are consistent with those reported by Raja and Bagle in 2005.

Length of leafrachis

The length of leaf rachis exhibited highly significant and positive correlations with various traits. Specifically, it showed strong correlations with leaf length (cm) (0.795 and 0.988), number of inflorescences per plant (0.438 and 0.507), number of flowers per inflorescence (0.405 and 0.494), number of pods per inflorescence (0.435 and 0.518), number of pods per plant (0.572 and 0.634), marketable pod length (cm) (0.545 and 0.674), number of seeds per pod (0.381 and 0.787), marketable pod weight (g) (0.469 and 0.685), and marketable pod yield per plant (kg) (0.587 and 0.656) at both phenotypic and genotypic levels. Similar results were also reported by Karunkar *et al.* (2018) and Asati *et al.* (2021).

Leaf length (cm)

Leaf length (cm) exhibited highly significant and positive correlations with several traits. Specifically, it showed strong correlations with the number of inflorescences per plant (0.345 and 0.435), the number of flowers per inflorescence (0.344 and 0.435), the number of pods per inflorescence (0.471 and 0.583), the number of pods per plant (0.445 and 0.541), marketable pod length (cm) (0.419 and 0.600), marketable pod weight (g) (0.381 and 0.544), and marketable pod yield per plant (kg) (0.451 and 0.549) at both phenotypic and genotypic levels. Additionally, a significant correlation was observed with the number of seeds per pod (0.720) at the genotypic level. These findings are consistent with those reported by Dao *et al.* (2015).

Number of inflorescences per plant

Number of inflorescences per plant showed highly significant and positive correlation with number of flowers per inflorescence (0.497 and 0.559), number of pods per inflorescence (0.445 and 0.505), number of pods per plant (0.843 and 0.900), marketable pod length (cm) (0.601 and 0.709), number of seeds per pod (0.439 and 0.784), marketable pod weight (g) (0.553 and 0.803) and marketable pod yield per plant (kg) (0.827 and 0.889) at both phenotypic and genotypic levels.

Number of flowers per inflorescence

Number of flowers per inflorescence showed highly significant and positive correlation with number of pods per inflorescence (0.485 and 0.544), number of pods per plant (0.577 and 0.654) marketable pod length (cm) (0.550 and 0.730), number of seeds per pod (0.364 and 0.817) marketable pod weight (0.453 and 0.673 g) and marketable pod yield per plant (0.587 and 0.655 kg) at both phenotypic and genotypic levels. Similar result was also found by Verma *et al.* (2019) and Asati *et al.* (2021).

Number of pods per inflorescence

Number of pods per inflorescence exhibited a highly significant and positive correlation with the number of pods per plant (0.600 and 0.672), marketable pod length (cm) (0.470 and 0.672), number of seeds per pod (0.226 and 0.620), marketable pod weight (g) (0.383 and 0.606), and marketable pod yield per plant (kg) (0.596 and 0.662) at both phenotypic and genotypic levels. These findings corroborate those reported by Asati *et al.* (2021).

Number of pods per plant

Number of pods per plant showed highly significant and positive correlation with marketable pod length (cm) (0.672 and 0.811), number of seeds per pod (0.425 and 0.882), marketable pod weight (g) (0.614 and 0.890) and marketable pod yield per plant (kg) (0.939 and 0.924) at both phenotypic and genotypic levels. Similar result was also found by Karunkar *et al.* (2018).

Marketable pod Length (cm)

Marketable pod length (cm) showed highly significant and positive correlation with number of seeds per pod (0.570 and 0.955), marketable pod weight (g) (0.624 and 0.980) and marketable pod yield per plant (kg) (0.736 and 0.855) at both phenotypic and genotypical levels. Similar result was also found by Verma *et al.* (2019).

Pod girth (cm)

The pod girth (cm) not exhibited significant and positive correlation at either the phenotypic or genotypic levels.

Number of seeds per pod

The number of seeds per pod

demonstrated a significant and positive correlation with marketable pod weight (g) (0.569 and 0.885) and marketable pod yield per plant (kg) (0.476 and 0.842) at both phenotypic and genotypic levels. Similar findings were reported by Verma *et al.* (2019) and Selvakumari and Ponnuswami (2017).

Marketable Pod weight (g)

Marketable Pod weight (g) exhibited highly significant and positive correlation with marketable pod yield per plant (kg) (0.698 and 0.924) at both phenotypic and genotypical levels.Similar result was also found by Karunkar *et al.* (2018).

Path coefficient analysis provides a thorough understanding of contribution of various characters by partitioning the correlation coefficient into the measures of direct and indirect effects (Wright, 1921), Path analysis was carried out at genotypic levels considering marketable pod yield per plant (kg) as dependent variable and its attributes *viz.*, plant height (m), stem thickness (cm), number of primary branches per plant, length of leaf rachis, leaf length (cm), number of inflorescences per plant, number of flowers per inflorescence, number of pods per inflorescence, number of pods per plant, marketable pod length (cm), number of seeds per pod and marketable pod weight (g) as independent variables. Each component has two path actions *viz.,* direct effect on yield and indirect effect through components which are presented in Table 2.

Finding revealed that Number of pods per plant (0.945) expressed highest positive direct effect on marketable pod yield per plant (kg) and expressed high positive indirect effect *via* number of inflorescence per plant (0.850), marketable pod weight (g) (0.841), number of seed per pod (0.833), marketable pod length(cm) (0.767), number of pods per inflorescence (0.634), number of flower per inflorescence (0.618), length of leaf rachis (0.599), leaf length (cm) (0.511), plant height (m) (0.423), stem thickness (cm) (0.420) and number of primary branches per plant (0.325).

Marketable pod weight (g) (0.480) showed high positive direct effect on marketable pod yield per plant (kg) and expressed high positive indirect effect *via* number of seed per pod (0.642), marketable pod length (cm) (0.471), number of pods per plant (0.428), number of inflorescences per plant (0.386), length of leaf rachis (0.329), number of flowers per inflorescence (0.323) and stem thickness (cm) (0.320). Moderate positive indirect effect recorded through number of pods per inflorescence (0.291), plant height (m) (0.264), leaf length (cm) (0.261) and number of primary branches per plant (0.211).

Number of seed per pod (0.304) expressed high positive direct effect on marketable pod yield per plant. It exhibits moderate positive indirect effect *via* marketable pod length (cm) (0.290), number of pods per plant (0.268), number of flowers per inflorescence (0.248), length of leaf rachis (0.239), number of inflorescences per plant (0.238), leaf length (0.219) and it expressed low positive indirect effect *via* plant height (0.198), number of pods per inflorescence (0.188), stem thickness (cm) (0.187) and number of primary branches per plant (0.110).

Length of leaf rachis (0.273) exhibits moderate positive direct effect on marketable pod yield per plant. It expressed moderate positive indirect effect *via* leaf length (cm) (0.270), number of seeds per pod (0.215) and it showed low positive indirect effect *via* marketable pod weight (g) (0.187), Marketable pod length (cm) (184), Number of pods per plant (0.173), number of pods per inflorescence (0.141), number of inflorescences per plant (0.138), number of flowers per inflorescence (0.135).

Path coefficient analysis provides a thorough understanding of contribution of various characters by partitioning the correlation coefficient into the measures of direct and indirect effects (Wright, 1921), which helps the breeder in determining the marketable pod yield components. Path coefficient analysis revealed the positive indirect effect at genotypic level of the characters *viz.*, plant height (m), stem thickness (cm), number of primary branches per plant, length of leaf rachis, number of leaves per rachis, leaf length (cm), number of inflorescences per plant, number of flowers per inflorescence, number of pods per inflorescence, number of pods per plant, marketable pod length (cm), number of seeds per pod and marketable pod weight (g).

Number of pods per plant (0.945) expressed highest positive direct effect on marketable pod yield per plant followed by marketable pod weight (0.480), number of seeds per pod (0.304). Length of leaf rachis (0.273) exhibited moderate positive direct effect on marketable pod yield per plant whereas negligible positive direct effect on marketable pod yield per plant were reported in number of pods per inflorescence (0.085), number of primary branches per plant (0.033) and pod girth (0.027). Similar result was reported Raja and Bagle (2008), Karunakar *et al.* (2018), Verma *et al.* (2019) and Asati *et al.* (2021).

CONCLUSION

The study identified significant positive correlations between marketable pod yield and traits such as Marketable pod weight (g), Number of pods per plant and number of inflorescences per plant. Path coefficient analysis revealed that the number of pods per plant had the highest positive direct effect on marketable pod yield, followed by marketable pod weight and the number of seeds per pod. These insights highlight the importance of these traits in drumstick breeding programs focused on enhancing marketable pod yield. The results provide a foundation for selecting high-yielding genotypes and improving overall crop productivity.

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