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CORRELATION AND PATH COEFFICIENT ANALYSIS OF SOME ECONOMIC TRAITS IN MAHUA (*Madhuca indica* J.F. Gmel.)

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ABSTRACT

One hundred and sixty phenotypically superior mahua (*Madhuca indica*) trees from eastern Madhya Pradesh (India) were intensively assessed for 19 phenotypic traits of mahua tree, flowers and fruits. The correlation and path coefficient of phenotypic traits were established for use in tree improvement of this species. The flower dry weight was found positively and significantly ($p<0.01$) correlated with flower width (0.69), flower length (0.62) and flower fresh weight (0.55). Fruit and seed characters depicted significant and positive correlation with each other. The residual effect (R) of path analysis indicated that the studied characters contributed to about 73% of flower dry weight. Traits of flower dry and fresh weight, flower width, flower length, fruit weight, seed weight, reducing sugars, crown height and girth at breast height need to be given emphasis in the selection criteria for tree improvement of mahua.

Keywords: Correlation coefficient, mahua, path coefficient, tree improvement

INTRODUCTION

Mahua (*Madhuca indica* J.F. Gmel.) belongs to the family Sapotaceae and is a renowned NTFP of dry tropical and sub-tropical regions. Mainly valued for its flowers, it plays important role in supporting tribal livelihood of central India and is rightly known as ‘The tree for the poor” (Prasad, 1993; Nimbalkar *et al*., 2018a). The estimated production of mahua flower and seed in India is about 1 and 0.12 million tons, respetively (Patel *et al*., 2012). The species is well known as a sugar and oil yielding tree having wide adaptability and multitude uses. Very limited efforts have been directed to improve the tree as a crop plant because of long gestation period and slow growing nature. Also, its saplings and seedlings in wild are scarce but mature trees are common in farmers field and forest fringe areas. The observed wide gap in potential and actual yield is due to the use of locally available wild material. The species being an open pollinated crop has ample scope for genetic improvement through selection of superior trees with variation in flower and seed, yet no systematic diversity study and tree improvement programme for breeding superior high yielding genotypes has been initiated (Divakara, 2014; Nimbalkar *et al*., 2018b). Hence, there is urgent need to screen naturally available mahua genetic resources to select superior trees with commercially valuable traits of its flower.

Any trait/character is the resultant of different developmental and biochemical processes which occur from germination to maturity of an individual. It is essential to identify the causes of variability

The manuscript presents the work conducted by the first as a part of Ph.D. thesis research submitted to Forest Research Institute Deemed to be University, Dehradun, Uttra Khand (India) in the selected trait and its association with other traits so as to improve that trait (Meena *et al.*, 2016). Knowledge about the association between traits enables in assessing the impact of selection pressure exerted for a trait on other traits thereby manifests the direction and magnitude of such selection. Correlation analysis is one such statistical tools which determines mutual relationship between different plant traits. The path analysis is a standardized partial regression analysis developed by Wright (1923) and applied in tree improvement (Dewey and Lu, 1959). It is used to partition the correlation coefficients into direct effect through a given causal variable and indirect effects through alternate pathways (other causal variables) (Bisen *et al.*, 2010; Narolia *et al.*, 2012).

Very less information is available about the diversity existing in flowers, seeds and oil content in mahua (Hedge *et al.*, 2018; Nimbalkar *et al.*, 2018a). Diversity assessment in *M. latifolia* was carried out in Jharkhand on the basis of relationship of seed traits using 23 CPTs which suggested that the seeds with large breadth and high weight & oil content may be selected for producing better progenies (Divakara, 2014). Perusal of literature reveals no report about the relationship of phenotypic traits and their effect on mahua flowers. The present study was aimed to assess the nature and magnitude of relationships between 19 phenotypic traits of mahua tree, flower, fruits and seeds and their direct and indirect effects on commercially important trait of flower dry weight.

MATERIALS AND METHODS

One hundred and sixty phenotypically superior mahua (*M. indica*) trees of natural origin of 40-60 years age were selected from eight different locations of eastern Madhya Pradesh region (Fig. 1). The selected individuals were located between 23°06'49.16"N to 22°56'30.63"N latitudinal and 79°32'36.56"E to 81°41'51.47"E longitudinal ranges and within an altitudinal range of 315 to 679 meters. Intensive assessments were conducted for 19 phenotypic traits of mahua during 2016-2018. The morphometric characters of trees *viz.*, girth at breast height (GBH), tree height, crown spread, crown height and number of primary branches were considered. The tree height was measured using altimeter while crown height, crown spread and GBH were measured using standard measuring tape in the field.

The fresh flowers were collected individually from all the selected trees and their fresh weight recorded in field. The collected flowers were then brought for further analysis to Tropical Forest Research Institute, Jabalpur where they were sun-dried in a clean and dry place. Flower traits *viz.*, flower dry weight, flower length and flower width were recorded. Total carbohydrates, reducing sugars and total phenols were estimated in flowers. Alcoholic extract of dry pulverized flowers was obtained by cold maceration method and their phytochemical estimations were carried out in three replications by respective standard methods using Shimadzu spectrophotometer. The total carbohydrates in flower samples were determined by Anthrone method (Hedge and Hofreiter, 1962) while reducing sugars were determined and quantified using dinitro-salicylic acid method

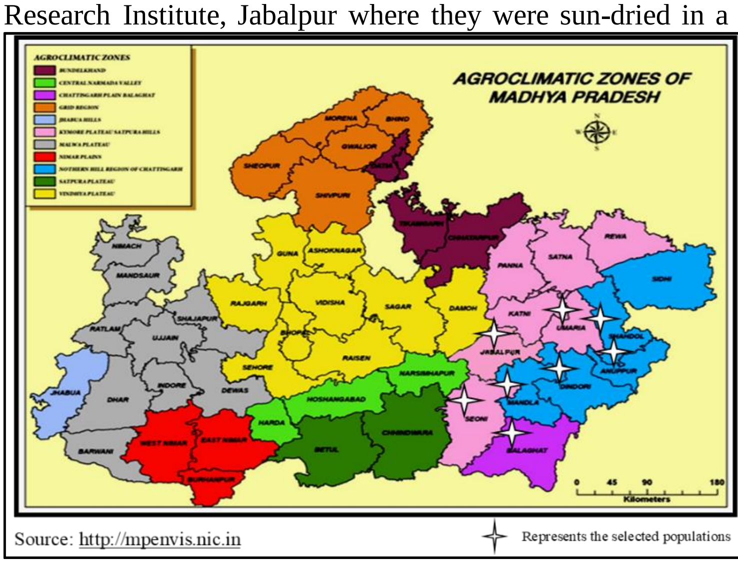

Fig. 1: Locations of selected populations depicted on the map of agro-climatic zones of Madhya Pradesh

(Miller, 1972). Total phenol content in mahua flowers was estimated by Folin-Ciocalteau reagent method (Folin and Ciocalteu, 1927). The different fruit traits assessed were weight, width and length. Seeds were extracted from the fruits and the weight, width and length of seeds measured. Seed coat was removed manually using scalpels (decortication) and seed kernels stored in oven at 40-45ºC. Oil was extracted in Soxhlet apparatus from powdered seed kernels using petroleum ether for 8-10 h at 70-80ºC.

The data was subjected to statistical analysis for Pearson correlation coefficient using SPSS ver.16 which was further partitioned into direct and indirect effects with the help of path coefficient analysis using OPSTAT (Sheoron *et al.*, 1988). Flower dry weight was considered as dependent variable and it was assumed to be influenced by the other characters called independent variables.

RESULTS AND DISCUSSION

The majority of desirable traits are complex in their genetic behaviour because of the interaction between a number of components. The understanding of the relationship between different economic traits is of paramount importance for making the best use of these relations in the selection of promising genotypes (Maurya *et al.*, 2015). Correlation establishes the extent and cause of association between important economic traits, so these components may form additional criteria for selection (Divakara, 2014). Loha *et al.* (2006) suggested that correlated quantitative traits are extremely important in tree improvement as improving one character may cause simultaneous changes in other character. Tree morphometric character of crown height showed highly significant and positive correlation (0.96) with and tree height. Crown height and crown diameter exhibited significant and positive correlation with morphometric characters *viz.*, tree height ($p<0.01$) and number of primary branches ($p<0.05$). Although, the number of primary branches exhibited significant positive correlation with crown height and crown diameter, yet it showed least correlation with other morphometric traits (Table 1).

The correlations amongst the economically important floral traits revealed that all the morphometric traits *viz.*, fresh weight, dry weight, length and width of flowers had high positive significant correlation with one another at $p\leq 0.01$ level. The findings are in line with Dominguez *et al.* (1998) who reported significant positive significant correlation for the flower morphometric traits in *Rhizophora mangle.* Similar positive correlation was also found among all the biochemical traits studied i.e. total carbohydrates, reducing sugars and total phenols. There was high positive correlation between total carbohydrates and reducing sugars (0.72), followed by the correlation between total carbohydrates and total phenols (0.23) at $p\leq 0.01$. The total phenols showed positive significant correlation with reducing sugars (0.16) at $p\leq 0.05$. Primack (1987) predicted that the plant species with larger flowers have large fruits while those with smaller flowers may have large or small fruits as the morphological continuity develop from flower to fruit as the ovary of flower forms the fruits. These are in conformity with the correlation of morphometric traits of flower and fruits in our study.

The fruit and seed morphometric traits in present study showed direct relationship with each other. Our results were similar to the findings of Hathurusingha *et al.* (2011) who observed a strong positive correlation between seed and fruit width of *Calophyllum inophyllum* and Metougui *et al.* (2017) who reported positive significant correlation between fruit and seed size and weight in *Argania spinosa.* In pesent study the morphometric characters of fruits *viz.*, weight, width and length showed highly significant positive correlation with one another ($p<0.01$). The fruit weight showed significant positive correlation with the measured morphometric traits of fruit width ($p<0.05$) and length ($p<0.01$) while the length and width were found correlated (Table 1).

Positive correlation was observed among all the seed traits *viz.*, seed weight, width, length and oil. The seed weight showed significant increase with increase in the length and width of seed. The

Table 1: Phenotypic correlation matrix for different morphometric traits of phenotypically superior trees *Madhuca indica*

Traits/ Character#		Tree traits					Flower traits							Fruit traits			Seed traits			
		GBH	TH	CH	CD	NPB	FlF Wt	FlDWt	FlW	FlL	TC	RS	TP	FrWt	FrW	FrL	SWt	SW	SL	SO
Tree trait	GBH	1.00																		
	TH	0.29**	1.00																	
	CH	0.28**	0.96**	1.00																
	CD	0.47**	0.39**	0.43**	1.00															
	NPB	0.10	0.17*	0.20*	0.20*	1.00														
Flower traits	FlFWt	-0.16*	0.11	0.09	0.10	0.001	1.00													
	FlDWt	0.02	0.20*	0.21**	0.16*	0.11	0.55**	1.00												
	FlW	-0.04	0.07	0.09	0.07	0.24**	0.45**	0.69**	1.00											
	FlL	0.03	0.23**	0.21**	0.17*	0.01	0.47**	0.62**	0.25**	1.00										
	TC	-0.17*	0.05	0.13	0.02	0.23**	0.07	0.10	0.21**	-0.14	1.00									
	RS	-0.09	0.03	0.09	0.04	0.23**	0.09	0.15	0.22**	-0.10	0.72**	1.00								
	TP	-0.13	0.03	-0.004	0.05	0.12	0.14	-0.06	-0.06	0.03	0.23**	0.16*	1.00							
Fruit	FrWt	-0.14	0.04	0.04	0.06	0.15	0.28**	0.28**	0.19*	0.23**	0.09	0.04	0.12	1.00						
	FrW	-0.16*	0.02	0.04	0.02	0.02	0.28**	0.23**	0.19*	0.16*	0.17*	0.11	0.06	0.59**	1.00					
	FrL	-0.10	0.00	0.01	0.03	0.10	0.02	0.13	0.13	0.15	0.06	0.09	-0.13	0.44**	0.33**	1.00				
Seed traits	SWt	-0.16*	-0.05	-0.01	0.03	0.12	0.08	0.10	0.17*	-0.09	0.33**	0.32**	-0.12	0.23**	0.46**	0.43**	1.00			
	SW	-0.19*	-0.12	-0.09	0.06	0.10	0.14	0.13	0.15	0.11	0.12	0.07	0.06	0.40**	0.53**	0.37**	0.51**	1.00		
	SL	0.03	0.08	0.09	0.15	0.30**	-0.02	0.05	0.08	0.05	0.08	0.15	0.04	0.26**	0.17*	0.54**	0.37**	0.34**	1.00	
	SO	-0.11	-0.12	-0.11	-0.20*	0.05	-0.10	-0.25**	-0.18*	-0.07	-0.07	-0.07	0.08	0.21**	0.06	0.21**	0.21**	0.16*	0.15	1.00

#TH = Tree height; CH = Crown height; CD = Crown diameter; NPB = Number of primary branches; FlFWt = Flower fresh weight; FlW = Flower width; FlL = Flower length; TC = Total carbohydrates; RS = Reducing sugars; TP = Total phenols; FrWt = Fruit weight; FrW = Fruit width; FrL = Fruit length; SWt = Seed weight; SW = Seed width; SL = Seed length; SO = Seed oil;

*Correlation significance at 0.05 level and **Correlation significance at 0.01 level

Table 2: Path-Coefficient analysis with different morphometric traits in *Madhuca indica*

Traits/ Character#		Corr-elation with FlDWt	Direct effect	Tree traits					Flower traits						Fruit traits			Seed traits			
				GBH	TH	CH	CD	NPB	FlFWt	FlW	FlL	TC	RS	TP	FrWt	FrW	FrL	SWt	SW	SL	SO
	GBH	0.03	0.04	--	-0.004	0.015	-0.008	-0.004	-0.013	-0.017	0.011	0.002	-0.007	0.007	-0.020	0.016	0.005	-0.015	0.005	-0.001	0.015
	TH	0.20*	-0.02	0.013	--	0.051	-0.004	-0.008	0.009	0.031	0.104	-0.001	0.002	-0.001	0.006	-0.001	0.000	-0.004	0.003	0.001	0.017
	CH	0.20*	0.05	0.008	-0.005	--	-0.004	-0.009	0.007	0.034	0.093	-0.002	0.007	0.000	0.006	-0.001	-0.001	-0.001	0.002	-0.001	0.016
	CD	0.17*	-0.02	0.014	-0.002	0.020	--	-0.009	0.008	0.042	0.075	0.000	0.003	-0.003	0.009	-0.001	-0.002	0.003	-0.001	-0.002	0.028
	NPB	0.13	-0.04	0.003	-0.001	0.009	-0.002	--	0.000	0.138	0.005	-0.003	0.017	-0.006	0.022	-0.001	-0.005	0.011	-0.002	-0.004	-0.008
Flower traits	FlFWt	0.55**	0.08	-0.006	-0.001	0.004	-0.001	0.000	--	0.215	0.210	-0.001	0.007	-0.007	0.040	-0.011	-0.001	0.008	-0.003	0.000	0.015
	FlW	0.68**	0.48	-0.004	0.000	0.004	-0.001	-0.011	0.036	--	0.113	-0.003	0.016	0.003	0.027	-0.007	-0.007	0.015	-0.004	-0.001	0.025
	FlL	0.60**	0.45	0.001	-0.001	0.009	-0.002	0.000	0.028	0.123	--	0.002	-0.007	-0.001	0.014	-0.006	-0.008	-0.008	-0.003	-0.001	0.010
	TC	0.12	-0.01	-0.007	0.000	0.006	0.000	-0.010	0.006	0.126	-0.062	--	0.052	-0.012	0.013	-0.007	-0.003	0.030	-0.003	-0.001	0.009
	RS	0.17*	0.07	-0.004	0.000	0.004	0.000	-0.010	0.007	0.126	-0.042	-0.009	--	-0.008	0.006	-0.004	-0.005	0.030	-0.002	-0.002	0.010
	TP	-0.04	-0.05	-0.005	0.000	0.000	-0.001	-0.005	0.011	-0.029	0.012	-0.003	0.011	--	0.017	-0.002	0.007	0.011	-0.001	-0.001	-0.011
Fruit trait	FrWt	0.29**	0.15	-0.004	0.000	0.002	-0.001	-0.007	0.022	0.079	0.103	-0.001	0.003	-0.006	--	-0.022	-0.023	0.021	0.010	-0.004	-0.030
	FrW	0.21**	-0.04	-0.006	0.000	0.002	0.000	-0.001	0.012	0.091	0.072	-0.002	0.008	-0.003	0.075	--	-0.017	0.042	-0.013	-0.002	-0.009
	FrL	0.16*	-0.05	-0.004	0.000	0.001	0.000	-0.004	0.002	0.081	0.076	-0.001	0.006	0.007	0.064	-0.013	--	0.039	-0.009	-0.007	-0.029
Seed traits	SWt	0.1	0.10	-0.005	0.000	-0.001	0.000	-0.005	0.007	0.081	-0.041	-0.004	0.023	0.006	0.033	-0.017	-0.022	--	-0.012	-0.005	-0.030
	SW	0.11	-0.02	-0.007	0.001	-0.004	-0.001	-0.004	0.011	0.072	0.048	-0.001	0.005	-0.003	0.049	-0.020	-0.019	0.038	--	-0.005	-0.023
	SL	0.07	-0.02	0.000	0.000	0.004	-0.001	-0.013	-0.002	0.039	0.034	-0.001	0.011	-0.002	0.038	-0.007	-0.028	0.044	-0.008	--	-0.022
	SO	-0.22**	-0.14	-0.002	0.001	-0.005	0.002	-0.002	-0.008	-0.066	-0.032	0.001	-0.005	-0.004	0.041	-0.002	-0.011	0.019	-0.004	-0.002	--

#TH = Tree height; CH = Crown height; CD = Crown diameter; NPB = Number of primary branches; FlFWt = Flower fresh weight; FlW = Flower width; FlL = Flower length; TC = Total carbohydrates; RS = Reducing sugars; TP = Total phenols; FrWt = Fruit weight; FrW = Fruit width; FrL = Fruit length; SWt = Seed weight; SW = Seed width; SL = Seed length; SO = Seed oil;

*Correlation significance at 0.05 level and **Correlation significance at 0.01 level

seed oil was found least correlated trait but was correlated with seed weight and width at $p<0.01$ and $p<0.05$, respectively. Considering the correlation between fruit and seed traits, it was observed that all the morphometric traits of fruits *viz*., fruit weight, width and length were significant positively correlated ($p<0.01$) with all the morphometric traits of seeds *viz*., seed weight, seed width and length. Significant positive correlation was observed between seed oil and morphometric traits of fruits *viz*., fruit weight ($p<0.01$) and length ($p<0.01$) and seed traits *i.e.*, seed weight ($p<0.01$) and width ($p<0.05$) (Table 1). This may be attributed to morphological and resource allocation continuity from flower to fruit to seeds (Primack, 1987). Abraham *et al.* (2010) and Divakara (2014) reported significant positive correlation between 100 seed weight with seed length, breadth and thickness in mahua (*M. longifolia* and *M. latifolia*). Our results are in conformity with Kaushik *et al.* (2007a); Kaushik *et al.* (2007b) and Aabd *et al.* (2010) who reported strong relationship between seed weight and oil content in *Jatropha curcas*, *Pongamia pinnata* and *Argania spinosa*. Divakara (2014) found positive correlation of 100 seed weight and oil content with the growth of mahua (*M. latifolia*) at juvenile stage and suggested that clear understanding of relationship among different seed and progeny traits is very essential. Although Khalil (1981) in case of *Picea glauca* and Robinson and Buijtenen (1979) in case of *Pinus* spp.observed that such correlation effect exist in initial growth years but disappear with growing age of seedings. Seed weight depends on the reserve food material *i.e.*, endosperm which is produced as a result of double fertilization and is influenced by the nutrient availability at the time of seed setting and environmental factors besides the dominant maternal and paternal traits (Allen, 1960; Johhnsen *et al.*,1989). The seed oil showed non-significant negative correlation with morphometric characters of tree which is in conformity with Kaura *et al.* (1998) in case of *Azadirachta indica.*

The correlation among various reproductive parts *i.e.*, flowers, fruits and seeds revealed a low significant ($p<0.01$) positive correlation for fresh and dry weight of flower with fruit weight and width. The flower width showed comparatively low but significant ($p<0.05$) correlation with fruit weight, fruit width and seed weight. However, flower length showed low but significant positive ($p<0.01$) correlation with fruit weight and width. The biochemical characters of flower, fruit and seeds were also observed for correlation between them and with morphometric traits. The seed oil had low negative significant ($p<0.01$) correlation with flower dry weight and width. The total carbohydrates and reducing sugars in flowers of mahua had positive significant ($p<0.01$) relationship with seed weight. The seed oil showed significant negative correlation with total carbohydrates of flowers (Table 1). Seeds store a large amount of storage materials, mostly carbohydrates (Ibrahim *et al.* ,1997); and in even slightly harsh conditions they produce seeds with lesser oil content (Rose, 1988). These results corroborate with those of Hathurusingha *et al.* (2011) who reported similar findings in *Calophyllum inophyllum*. As there is resource continuity from flower to seeds (Primack, 1987) it is possible that flowers having higher carbohydrate content may influence higher carbohydrate content in seeds of that genotype and hence reduce oil content in seeds.

Correlation analysis revealed overall relationship between different traits. It failed to provide exact picture of how much a character constitute on its own and via other characters as the dependent traits. Under such circumstances, path coefficient analysis is a helpful tool in the resolution of correlation into components of direct and indirect effects (Kumar and Dhillon, 2016). Hence, it is the net result of direct effect of a particular trait and indirect effects via other traits. Path analysis is a statistical technique used primarily to examine the comparative strength of direct and indirect relationship among variables and thus permits a critical examination of components that influence a given correlation and can be helpful in formulating an efficient selection strategy (Shipley,1997; Scheiner *et al.*, 2000). This approach quantifies the relationship among variables based on a prior assumption, which traits are to be included in analysis. Such assumptions are somewhat subjective but path coefficient may allow a better understanding of interrelationships between traits than correlation tables with all possible combinations between all the traits. The path diagram specifies the causal and non-causal paths between independent and dependent variables (Bisen *et al.*, 2010).

Path coefficient analysis provides better means for selection by resolving the correlation coefficient of flower dry weight and its components into direct and indirect effects. Meena *et al.* (2016) examined the path analysis for direct and indirect contributors in bell pepper and reported dry weight of red ripe fruits, fresh ripe fruit weight and number of seeds fruit^{-1} to be positively and significantly influenced by their fruit characters. Average fruits weight exibited direct effect in tomato

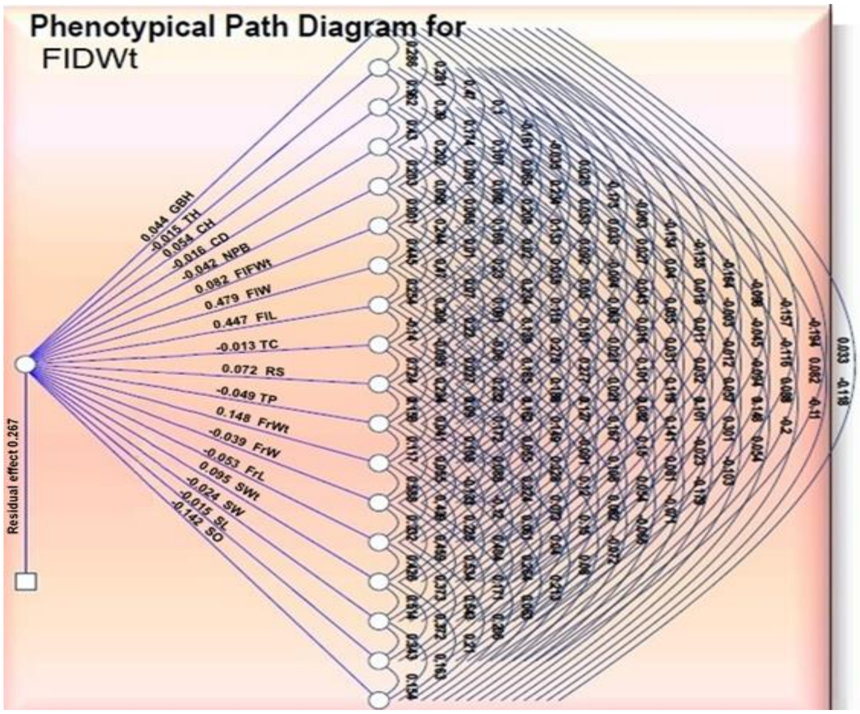

Fig. 2: Phenotypic path diagram for mahua flower dry weight

Where, TH = Tree height; CH = Crown height; CD = Crown diameter; NPB = Number of primary branches; FlFWt =Flower fresh weight; FlW =Flower width; FlL =Flower length; TC = Total carbohydrates; RS = Reducing sugars; TP = Total phenols; FrWt = Fruit weight; FrW = Fruit width; FrL = Fruit length; SWt = Seed weight; SW = Seed width; SL = Seed length; SO = Seed oil

(Narolia *et al.*, 2012). Similar results were reported by Mohanty (2003).

The path coefficient analysis for economically important flower trait (dry weight) was performed in mahua. The Pearson's correlation coefficient obtained with flower dry weight was partitioned into direct and indirect effects (Table 2). A critical perusal of path coefficient analysis revealed that the flower width followed by length showed highest positive direct effect (*i.e.* 0.48 and 0.45, respectively) on flower dry weight. However, the flower fresh weight exhibited lowest (0.08) direct effect among the floral morphometric traits. Among the morpho-metric characters of tree, two traits *viz*., crown height (0.05) and GBH (0.04) had highest magnitude of direct effect. The rest morphometric traits like tree height (-0.02) and crown diameter (-0.02) showed negative direct effect with dry flower weight, along with number of primary branches (-0.04). In case of fruit and seed traits, the weight of both fruit and seed showed positive direct effect (0.15 and 0.10, respectively) on flower dry weight. The remaining fruit traits, seed width and length showed negative direct effect with the flower dry weight. Interpretation of direct effect of flower dry weight on chemical traits of flower and seed revealed negative direct effect on total carbohydrates (-0.01) and phenols (-0.05) of flowers and the seed oil (-0.14). The residual effect (R) of path analysis indicated that the characters studied contributed around 73% of flower dry weight. It also indicated that some other factors not included in the present study contributed 27% to the flower dry weight (Fig. 2). A residual effect of 50.6 has been reported in tomato (Narolia *et al.*, 2012) and15.66 in sorghum hybrids (Bisen *et al.*, 2010).

During selection of superior trees in mahua, more weightage should be given to the flower dry weight, flower width, flower length, fruit weight, seed weight, flower fresh weight, reducing sugars, crown height and GBH. These economically important flower traits could be regarded as important components in influencing dry weight of mahua flower.

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