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Character Identification for Tree Species Selection using Path Analysis in Agro-forestry Systems

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ABSTRACT

Performance of the tree species depends on intercrop considered and on number of tree species characters. The tree characters in turn are interrelated and some have direct/indirect effect on the trait of measure of interest (*viz.*, wood volume). Among the tree characters studied, GBH is having appreciable positive relation with wood volume and the same character is having better direct effect for increase in wood volume. GBH may be considered as a tree character for selection of tree species in intercropping with finger millet. Bole height which also have better direct effect on wood volume next to GBH can also be considered for selection of tree species for intercropping with finger millet. Low residual effect has revealed association to the extent of 95 to 98 per cent in the tree species characters considered except *Melia azedarach* which recorded only 29.45 per cent association.

Keywords : Agro-forestry system, path analysis, tree characters

AGRO-FORESTRY is defined as the deliberate integration of woody species with agricultural crops and/or pastures on the same land-unit resulting in the integration of economical and ecological interactions between components. In agro-forestry, tree and agricultural crops are combined together and they compete with each other for growth resources such as light, water and nutrients. The resource sharing by the components may result in complementary or competitive effects depending upon the nature of the species involved in the system. Growing manner in the system are depending on the climatic factors, plants and trees may influence neighboring species, not only by the addition or removal of some factor, but also by affecting conditions such as temperature, light or wind movement or by altering the balance between beneficial and harmful organisms (Ram Newaj *et.al.*, 2005). Agro-forestry systems not only arrest land degradation but also improve site productivity through interactions among trees, soil, crops and livestock (Kumar *et al.*, 2011). The ultimate goal of the agro-forestry system is identification of combination of tree species and field crops.

Performance of the tree species depends on intercrop considered and on number of its component characters. The tree characters in turn are interrelated and some have direct/indirect effect on the trait of measure interest (wood volume). Hence, role of path co-efficient analysis becomes important.

Path analysis is a statistical technique that partitions correlations into direct and indirect effects. Correlation measures the extent and direction (positive or negative) of the relationship between two or more variables. The estimates of correlation and path coefficients can help us to understand the roles and relative contributions of various plant traits in establishing the growth behaviour of crop cultivars under given environmental conditions (Shahbaz Akhtar *et al.*, 2007).

In most of the studies direct/indirect effect on the trait of measure of interest are made for only one crop experiment. In this study a thought has been made to know the effect of growth contributing characters of different tree species which are grown with finger millet. This will help in identification of tree for the intercrop with finger millet based on direct effect of tree characters. In the present study, associations of each contributing trait to wood volume of different tree species grown with finger millet are made

followed by analysis of direct and indirect effect. Correlation study coupled with path analysis is more effective tool to identify suitable tree species for intercropping.

MATERIAL AND METHODS

The data was obtained from ongoing experiment of AICRP on agro-forestry in Agro-forestry, UAS, GKVK, Bangalore. Geographically it is situated in the Eastern Dry Zone (Zone-5) of Karnataka. The experimental site is located between 12^0 51' N latitude and 77^0 35' E longitude at an altitude of 930 m above mean sea level (MSL).

Secondary data of wood volume (m^3) along with their growth characters such as : Tree height (m), Bole height (m), GBH (cm) and Canopy spread in north-south direction (m) of the seven biofuel tree species such as *Simarouba glauca, Melia dubia, Azadirachta indica, Melia azedarach, Pongamia pinnata, Madhuca latifolia, Calophyllum inophyllum* grown with finger millet has been considered for the study. Similarly, observations on growth and yield parameters of finger millet were recorded from five randomly selected plants from the net plot area. Observations were taken at two directions *i.e.*, towards north and south, of tree rows and also at two distances 2.5 m and 5 m from the base of each tree. The data were recorded on all the above characters for the period from 2011-2014.

Growth characters of tree species may have different effect on wood volume, hence direct/indirect effects of these on wood volume have been studied using the path analysis. Path analysis has been performed first by subjecting data to correlation analysis and further splitting it for their direct/indirect effects on the character of interest (wood volume). Correlation coefficients were computed among wood volume and the tree species characters separately using the formula

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

Path analysis: A character of interest Y is determined by three correlated variables, *viz.*, X_1, X_2 and X_3. The relationship can be expressed in the form of a partial regression equation as

$$Y = \mu + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + R$$

where, β_1, β_2 and β_3 are the partial regression coefficients. β_1 the partial regression coefficient of Y on X_1, measures the amount of change that can be brought about in Y due to one unit change in X_1, keeping X_2 and X_3 constant. R is the residual component.

B_i (σ_{xi}/ σ_y) is a standardized partial regression coefficient is called as the 'path coefficient'. These path coefficients are worked as per the procedure outlined by Dabholkar (1992). Path coefficients have a direction similar to the regression coefficients, *i.e.*, they may bear a positive or a negative sign. Unlike the correlation coefficients, the path coefficients could be greater/less than unity like regression coefficients. These procedures permit to identify relatively important components of a dependent variable, on the basis of their direct and indirect influences.

Direct Effect: Every component character will have a direct effect (positive or negative) on yield. In addition, it will also exert indirect effect (positive or negative) *via* other component characters. These positive and negative direct effects may cause for increment/decrement in the response variable.

Indirect Effect: The effect of an independent character on the dependent one *via* other independent traits is known as indirect effects. The positive indirect effects will neutralize the negative direct effects.

Residual Effect: Residual effect measures the role of other possible independent variables which were not included in the study on the dependent variable. The residual effect is estimated with the help of direct effects and simple correlation coefficients (for 3 path coefficients) as given below

$$R^2 = 1 - a^2 + b^2 + c^2 + 2rx_1x_2ab + 2rx_1x_3ac + 2rx_2x_3bc$$

Results and Discussion

Wood volume (m^3) along with their growth characters *viz.,* Tree height (m), Bole height (m), GBH (cm) and Canopy spread in north-south direction (m) of the seven biofuel tree species grown along with finger millet as intercrop will have varied performance. Causing characters such as Tree Height, GBH and Canopy spread will have their own influence with the Wood volume. These get varied from species to species when grown with the finger millet. Results of the correlation analysis are presented in Table I.

Table I

Correlation of tree characters with wood volume

Tree species	Tree height	GBH	Bole height	Canopy spread in north south
Pongamia pinnata	0.3200 ^{NS}	0.9264 *	0.5912 *	0.8680 *
Melia dubia	0.9317 *	0.2817 ^{NS}	0.9814 *	0.5809 *
Simarouba glauca	0.6477 *	0.7807 *	0.2189 ^{NS}	-0.5345 *
Madhuca latifolia	0.3914 ^{NS}	0.9553 *	0.8508 *	0.6223 *
Calophyllum inophyllum	0.8819 *	0.8917 *	0.7615 *	0.6905 *
Azardirachta indica	0.8777 *	0.9605 *	0.8998 *	0.9074 *
Melia azedarach	0.1168 ^{NS}	0.9432 *	0.9048 *	- 0.1388 ^{NS}

* Significant at 5% level of significance

Results of Table I revealed that GBH (0.9264) and canopy spread in north-south direction (0.8680) have significant positive correlation with the wood volume for *Pongamia pinnata* when grown with finger millet. Bole height (0.9814), tree height (0.9371) and canopy spread in north south direction (0.5809) have significant positive correlation with the wood volume of *Melia dubia*. Correlation analysis results for *Simarouba glauca* reveals that, GBH (0.7807) and tree height (0.6477) have positive significant correlation with wood volume. Correlation coefficients worked out for *Madhuca latifolia* shows that, GBH (0.9553), canopy spread in north-south direction (0.6223) and bole height (0.8508) has significant positive correlation with the wood volume. In case of *Calophyllum inophyllum*, GBH (0.8917), tree height (0.8819), bole height (0.7615) and canopy spread in north-south direction (0.6905) have significant positive correlation with its wood volume. Results of Correlation analysis of *Azadirachta indica* reveals that there is significant positive correlation of GBH (0.9605), canopy spread in north-south direction (0.9074), bole height (0.8998) and tree height (0.8777) with the wood volume. The correlation coefficients worked out for *Melia azedarach* indicated that, GBH (0.9432) and bole height (0.9048) have significant positive correlation with the wood volume.

The characters which are found to be significant correlation with wood volume may cause for the increasing in the wood volume and these may be preferred for selection of the tree species. Raju Chavan *et al.* (2011) also observed highly significant positive correlation of biomass with tree height, bole height, GBH, number of branches, crown spread and volume of wood.

Results of Path coefficient analysis done to know the direct and indirect effects of tree growth characters on wood volume for each tree species are presented in Tables II to VIII and results of residual effect for each tree species are provided in Table IX.

Path analysis results tabulated in Table II for *Pongamia pinnata* indicated that, GBH (0.7996) is having high positive direct effect on wood volume followed by bole height (0.3853), Canopy spread and tree height are having positive indirect effect of 0.8330 and 0.3185, respectively on wood volume. These components have neutralized the low direct effect caused by them through other tree characters

Table II

Path analysis of wood volume with tree characters for Pongamia pinnata

Effect	Tree height	GBH	Bole height	Canopy spread
Direct	0.0013	0.7996	0.3853	0.0349
Indirect	0.3185	0.1267	0.2058	0.8330
R	0.3199	0.9263	0.5912	0.8679

Residual effect=0.0249

considered. It is observed that residual error is 0.0249, indicating that 97.50 per cent of cause and effect relationship between wood volume and the tree growth characters of *Pongamia pinnata* have explained by this association.

Path analysis results tabulated in Table III for *Melia dubia* revealed that, bole height (0.6440) and tree height (0.4186) are having positive direct effect on wood volume followed by GBH (0.0.0291). The tree characters canopy spread and GBH are having positive indirect effect of 0.5864 and 0.2526, respectively on wood volume. These components have neutralized the low direct effect caused by them through other tree characters considered. It is found that residual error is 0.047, indicating that 95.23 per cent of cause and effect relationship between wood volume and the tree growth characters of *Melia dubia* have explained by this association.

TABLE III

Path analysis of wood volume with tree characters for Melia dubia

Effect	Tree height	GBH	Bole height	Canopy spread
Direct	0.4186	0.0291	0.6440	-0.0055
Indirect	0.5131	0.2526	0.3373	0.5864
R	0.9317	0.2817	0.9814	0.5809

Residual effect=0.047

Path analysis results from Table IV for *Simarouba glauca* revealed that GBH (1.1388) has a higher direct effect on wood volume followed by bole height (0.7228). Higher indirect effect of tree height (0.6930) would neutralize the low direct effect caused by it through other tree characters considered. Residual error under *Simarouba glauca* was found to be 0.0181, depicting 98.18 per cent of the cause and effect relationship between wood volume and the tree growth characters have explained by this association.

TABLE IV

Path analysis of wood volume with tree characters for Simarouba glauca

Effect	Tree height	GBH	Bole height	Canopy spread
Direct	-0.0453	1.1388	0.7228	0.0343
Indirect	0.6930	-0.3581	-0.5038	-0.5688
R	0.6476	0.7807	0.2189	-0.5345

Residual effect=0.0181

Results tabulated in Table V for *Madhuca latifolia* indicated that, GBH (0.6918) is having positive direct effect followed by bole height (0.3721). Higher indirect effect of canopy spread (0.6467) would neutralize the low direct effect caused by it through other tree characters considered. It is observed that residual error is 0.0381, indicating that 96.19 per cent of cause and effect relationship between wood volume and the tree growth characters of *Madhuca latifolia* have explained by this association.

TABLE V

Path analysis of wood volume with tree characters for Madhuca latifolia

Effect	Tree height	GBH	Bole height	Canopy spread
Direct	0.0926	0.6918	0.3721	-0.0244
Indirect	0.2987	0.2634	0.4786	0.6467
R	0.3913	0.9552	0.8507	0.6222

Residual effect=0.0381

For *Calophyllum inophyllump,* path analysis results are presented in Table VI. Results revealed that there was a higher positive direct effect was found with GBH (0.7186) followed by bole height (0.4517). Higher positive indirect effects of canopy spread (0.7845) and tree height (0.7930) neutralized the low direct effect caused by them through other tree

TABLE VI

Path analysis of wood volume with tree characters for Calophyllum inophyllum

Effect	Tree height	GBH	Bole height	Canopy spread
Direct	0.0888	0.7186	0.4517	-0.0941
Indirect	0.7930	0.1730	0.3097	0.7845
R	0.8819	0.8916	0.7615	0.6904

Residual effect=0.0423

characters considered. It is observed that residual error is 0.0423, indicating that 95.77 per cent of cause and effect relationship between wood volume and the tree growth characters of have explained by this association.

Path analysis results presented in Table VII for *Azadirachta indica* indicated that GBH (0.6595) and bole height (0.4120) were found to be having a higher positive direct effect on wood volume. Higher positive indirect effects of canopy spread (0.9200) and tree height (0.8721) will neutralize the low direct effect caused by them through other tree characters

TABLE VII

Path analysis of wood volume with tree characters for Azardirachta indica

Effect	Tree height	GBH	Bole height	Canopy spread
Direct	0.0055	0.6595	0.4120	-0.0126
Indirect	0.8721	0.3008	0.4876	0.9200
R	0.8776	0.9604	0.8997	0.9074

Residual effect=0.0482

considered. Residual error is 0.0482, indicating that 95.17 per cent of cause and effect relationship between wood volume and the tree growth characters of *Azadirachta indica* have explained by this association.

Results of path analysis tabulated in Table VIII for *Melia azedarach* revealed GBH (0.6305) and bole height (0.4515) were found to be having a higher positive direct effect on wood volume. Positive indirect effect of tree height (0.1225) will neutralize the low direct effect caused by it through other tree characters considered. It is observed that residual error

TABLE VIII

Path analysis of wood volume with tree characters for Melia azedarach

Effect	Tree height	GBH	Bole height	Canopy spread
Direct	-0.0058	0.6305	0.4515	0.0243
Indirect	0.1225	0.3126	0.4532	-0.1631
R	0.1167	0.9432	0.9047	-0.1387

Residual effect=0.7054

is 0.705, indicating that 29.45 per cent of cause and effect relationship between wood volume and the tree growth characters of *Melia azedarach* have explained by this association.

Daniya *et. al*. (2013) indicated in their study of Correlation and Path Analysis in sesame that, well inter–dependency existing between characters of yield determinants. Better inter dependency is also reported by Muhamman *et al*. (2010), Tamina and Tapash (2011) and Haruna *et al*. (2012) between characters of influence and final seed yield in sesame.

Results of residual effect observed in path analysis are presented in Table IX. From the results it could be observed that, residual effect is noticed to be low with all the tree species (0.0249, 0.0477, 0.0181, 0.0381, 0.0423, 0.0482) for *Pongamia pinnata, Melia dubia, Simarouba glauca, Madhuca latifolia, Calophyllum inophyllum, Azardirachta indica,* respectively except *Melia azedarach* (0.7054). This indicated that there is better association with the tree characters on wood volume when grown with finger millet as intercrop. The association is to the extent of 95 to 98 per cent except *Melia azedarach* which recorded only 29.45 per cent association.

TABLE IX

Residual effect and per cent explained

Tree species	Residual error	Per cent explained
Pongamia pinnata	0.0249	97.50
Melia dubia	0.0477	95.23
Simarouba glauca	0.0181	98.18
Madhuca latifolia	0.0381	96.19
Calophyllum inophyllum	0.0423	95.77
Azardirachta indica	0.0482	95.17
Melia azedarach	0.7054	29.45

Among the tree characters, GBH is having appreciable positive relation with wood volume and same character is having better direct effect for increase in wood volume. GBH may be considered as a tree character for selection of tree species in

intercropping with finger millet. Bole height which also have better direct effect on wood volume next to GBH can also be considered for selection of tree species for intercropping with finger millet.

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