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EFFECT OF INTEGRATED NUTRIENT MANAGEMENT PRACTICES ON GROWTH AND ECOPHYSIOLOGICAL CHARACTERS OF *DALBERGIA SISSOO* ROXB. CLONES

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ABSTRACT

A field experiment was carried out in 2012-14 to study the growth and ecophsiological characters of *Dalbergia sissoo* clones. The study area was located at TNPL, Karur (11º03´44.33" N latitude and 77º59´19.95" E longitude) Tamil Nadu, India. The experiment was conducted in randomized block design with four replications. Among the six different treatment combinations, 125% of Soil Test Value (STV) (138:98:65 NPK kg ha-1)+ VAM (100g plant-1) + Azospirillum (50g plant-1) + Phosphobacteria (50g plant-1) + FYM (500g plant-1) recorded the maximum values for growth parameters, ecophsiological characters followed by 100 % of STV (110:78:52 NPK kg ha-1) + VAM (100g plant-1) + Azospirillum (50g plant-1) + Phosphobacteria (50g plant-1) + FYM (500g plant-1). The results indicated that soil test value based integrated application of organics along with inorganic fertilizers positively influenced the growth, biomass and ecophsiological characters in *Dalbergia sissoo* clones during the initial growth stages

INTRODUCTION

Dalbergia sissoo Roxb. is one of the tropical timber tree species with multiple uses such as fuelwood, fodder, pulp, shade, shelter and N-fixing ability (Sharma *et al*., 2007). It is one of the few indigenous leguminous tree species of South Asia found growing naturally from Himalayan foot hills to the plains of Afghanistan, Malaysia, India and Pakistan. It is widely used in agroforestry, afforestation programmes and farm forestry in the Indian subcontinent (Huda *et al*., 2007). In dry deciduous forests, it has been reported to produce 15 tonnes ha^{-1} $year^{-1}$ of woody biomass (Rajvanshi *et al*., 1985) and a total biomass of 160 tonnes ha^{-1} $year^{-1}$ (Sharma *et al*., 1988). In the recent times, it is cultivated under high density as an irrigated tree crop for pulpwood. Studies on the evaluation of sissoo are limited to comparison of seedlings with clones. Evaluation of sissoo in a particular location becomes essential to assess the utilizable biomass and to provide the highest profit to the stakeholders. In order to bridge the gap between demand and supply of industrial wood besides reducing its rotation, new technologies have to be evolved through application of intensive location specific silvicultural practices. Integrated Nutrient Management (INM) is a recently developed practice which optimizes the performance of plants through augmentation of chemical and biological properties of soil. Adopting INM practices in trees can help in boosting the biomass productivity per unit area. Effective utilization of a combination of biofertilizers, organic and inorganic fertilizers improves and maintains the soil fertility.

Systematic efforts to test selected clonal material of *Dalbergia sissoo* under location specific conditions for estimation of its eco physiological parameters are meagre. Under location specific condition, the performance of clonal source of this species has to be tested for estimating the effect of integrated nutrient management on ecophysiological parameters in relation with producing more utilizable biomass. This study was, therefore, undertaken to study growth and ecophysiological parameters of *Dalbergia sissoo* clones.

MATERIALS AND METHODS

A field experiment was carried out at Tamil Nadu Newsprints and Papers Limited (TNPL), Karur (11º03′44.33” N latitude and 77º59′19.95” E longitude) Tamil Nadu, India. The mean annual rainfall of the site was 635 mm. The initial soil properties of the study area showed that the soil was red sandy loam with pH 6.3 and EC 0.10 d Sm^{-1}. The soil available nitrogen, P_2O_5 and K_2O content were 220, 10.0 and 330 kg ha^{-1} respectively. The design of the experiment was RBD and replicated four times. There were six treatments *viz.,* T_1 – Control, T_2 – Recommended dose of fertilizer (RDF) alone - 110:65:65 NPK kg ha^{-1}, T_3 – Soil Test Value (STV) alone – 110:78:52 NPK kg ha^{-1}, T_4 – 75 % of STV – 83:59:39 NPK kg ha^{-1} + VAM (100g $plant^{-1}$) + *Azospirillum* (50g $plant^{-1}$) + Phosphobacteria (50g $plant^{-1}$) + FYM (500g $plant^{-1}$), T_5 – 100 % of STV- 110:78:52 NPK kg ha^{-1} + VAM (100g $plant^{-1}$) + *Azospirillum* (50g $plant^{-1}$) + Phosphobacteria (50g $plant^{-1}$) + FYM (500g $plant^{-1}$), T_6 – 125% of STV 138:98:65 NPK kg ha^{-1} + VAM (100g $plant^{-1}$) + *Azospirillum* (50g $plant^{-1}$) + Phosphobacteria (50g $plant^{-1}$) + FYM (500g $plant^{-1}$). New shoots were collected from *D. sissoo* clonal garden maintained by TNPL for clonal propagation. Two month old clones *of Dalbergia sissoo* was planted during November, 2012 in 40 cm^3 size pit at 3 x 1.5m spacing. There were 24 plants per treatment; irrigation was given at weekly intervals.

The required amounts of each fertilizer and manure were applied 30 cm away from tree base to avoid the risk of loss over the surface. Biometric observations on plant height (cm) and basal diameter (mm) were recorded at 3, 6, 9, 12, 15 and 18 month after planting (MAP). The total chlorophyll, chlorophyll a and b were estimated by adopting the method suggested by Yoshida et al. (1971) and expressed in mg g^{-1} of fresh weight. For root studies, one representative plant sample was removed at 18 months after planting from each plot and roots of the plant were excavated and the dry weight was recorded after oven drying the samples and expressed in g $plant^{-1}$. The physiological traits were measured using a Portable Photosynthesis System (PPS, model CI-301 CO_2 gas analyzer, CID and Inc. USA). The net photosynthetic rate were measured on a sunny day between 10.00 AM to 11.00 AM as per the procedures and expressed as μ mol m^{-2} $s^{-1.}$ The measurements were made on fully matured leaves at six months interval. The transpiration rate measurements were made on fully matured leaves at six months interval and expressed as m mol $m^{-2}s^{-1}$ The stomatal conductance was measured and expressed in m mol m^{-2} s^{-1} The data were subjected to analysis of variance using SPSS / PC+ (1986) statistical package to test the significance of difference in the studied parameters due to the treatments.

RESULT AND DISCUSSION

The results revealed that, 125 % of STV (138:98:65 NPK kg ha^{-1}) + VAM (100 g $plant^{-1}$) + *Azospirillum* (50 g $plant^{-1}$) + Phosphobacteria (50 g $plant^{-1}$) + FYM (500 g $plant^{-1}$) (T_6) resulted in the highest value for tree height in all the months of observations. The percentage increase recorded over control was 21.05, 28.65, 55.17, 74.19, 72.37 and 85.95 per cent respectively in 3, 6, 9, 12, 15 and18 MAP. At the same time, height increment recorded over RDF was 17.94, 13.37, 23.53, 47.95, 53.14 and 50.08 per cent respectively (Table 1). The finding was in tune with the fact that addition of inorganic, organic and biofertilizer in combination favoured the growth of plants with higher rate of height due to continuous supply of nutrient by the quick release of inorganic fertilizers in the initial stages and the slow release of organic fertilizers and biofertilizers at the later stage.

Singh *et al.* (2005) proved that the response of *Dalbergia sissoo* and *Eucalyptus camaldulensis* in sodic soils, application of 50: 50: 50 NPK g $plant^{-1}$ at planting resulted in significant improvement in height of *Dalbergia sissoo* as observed after five years of planting. Rachmawati *et al.* (1996) observed a significant increase in height of *Dalbergia latifolia* with the application of urea fertilizer @ 90 g per hole in a vertisol dominated soil in Indonesia.

Tree basal diameter and DBH (cm) were found to be highest in 125 % of STV (138:98:65 NPK kg ha^{-1}) + VAM (100 g $plant^{-1}$) + *Azospirillum* (50 g $plant^{-1}$) + *Phosphobacteria* (50 g $plant^{-1}$) + FYM (500 g $plant^{-1}$) (T_6), during all the months of observation. During 9 MAP basal diameter (cm) of *Dalbergia sissoo*

Table 1. Effect of INM on height (m) of *Dalbergia sissoo*

Treatment	Height (m)						
	3 MAP	6 MAP	9 MAP	12 MAP	15 MAP	18 MAP	Mean
T_1	1.14	1.78	2.03	3.10	4.38	4.77	2.87
T_2	1.17	2.02	2.55	3.65	4.93	5.91	3.37
T_3	1.20	2.01	2.57	3.96	6.28	6.92	3.82
T_4	1.32	2.03	2.64	4.22	6.40	7.28	3.98
T_5	1.34	2.12	2.91	4.83	7.00	7.75	4.33
T_6	1.38	2.29	3.15	5.40	7.55	8.87	4.77
Mean	1.26	2.04	2.64	4.19	6.09	6.92	
SEd	0.0246	0.0349	0.1566	0.2087	0.1949	0.1391	
CD(P=0.05)	0.0524	0.0744	0.3337	0.4448	0.4154	0.2965	

Table 2. Effect of INM on diameter (cm) of *Dalbergia sissoo*

Treatment	Basal diameter (cm)				Diameter at Breast Height (DBH) (cm)			
	3 MAP	6 MAP	9 MAP	Mean	12 MAP	15 MAP	18 MAP	Mean
T_1	0.99	1.99	2.49	1.82	2.99	3.66	3.99	3.55
T_2	1.04	2.12	2.60	1.92	3.09	3.77	4.59	3.82
T_3	1.08	2.18	2.99	2.08	3.23	4.14	5.03	4.13
T_4	1.12	2.19	3.04	2.12	3.57	4.62	5.57	4.59
T_5	1.16	2.29	3.11	2.19	4.26	5.24	6.37	5.29
T_6	1.29	2.47	3.58	2.45	5.05	5.73	7.52	6.10
Mean	1.11	2.21	2.97		3.70	4.53	5.51	
SEd	0.0230	0.0753	0.2190		0.1933	0.3588	0.3393	
CD(P=0.05)	0.0491	0.1606	0.4668		0.4119	0.7648	0.7232	

was 3.58 cm whereas control recorded only 2.49 cm and RDF recorded 2.60 cm (Table 2). The observations of diameter at breast height level also toed the same line during the entire study period. During 18 MAP, 125 % of STV (138:98:65 NPK kg ha^{-1}) + VAM (100 g $plant^{-1}$) + *Azospirillum* (50 g $plant^{-1}$) + *Phosphobacteria* (50 g $plant^{-1}$) + FYM (500 g $plant^{-1}$) (T_6) showed 88.47 and 63.83 per cent increase over control and RDF. Hussain *et al.* (1990) stated that in *Dalbergia sissoo*, girth growth was best in 50 kg N/ha treatment and biomass production at 75 kg N/ha. Huda *et al.* (2007) concluded that PK at the rate of 160 kg/hm^2 fertilizer with soil and cowdung mixture (3:1) was optimum for obtaining collar diameter of *D. sissoo*.

Table 3. Effect of INM on chlorophyll content (mg g^{-1}) of *Dalbergia sissoo* at 18 MAP

Treatment	Chlorophyll a content (mg g^{-1})	Chlorophyll b content (mg g^{-1})	Total chlorophyll (mg g^{-1})
T_1	0.919	0.713	1.636
T_2	1.519	0.841	2.365
T_3	1.589	0.820	2.414
T_4	1.699	0.839	2.544
T_5	1.829	0.881	2.716
T_6	1.960	0.943	2.908
Mean	1.586	0.840	2.431
SEd	0.0099	0.0269	0.0798
CD(P=0.05)	0.0211	0.0572	0.1701

Table 4. Effect of INM on Net Photosynthetic Rate (µ mol m^{-2} s^{-1}) of *Dalbergia sissoo*

Treatment	Net Photosynthetic Rate (µ mol m^{-2} s^{-1})			
	6 MAP	12MAP	18MAP	Mean
T_1	10.65	13.51	7.34	10.50
T_2	11.76	16.58	7.99	12.11
T_3	12.42	17.76	10.11	13.43
T_4	12.75	17.93	10.62	13.77
T_5	13.24	18.21	10.73	14.06
T_6	13.63	18.22	11.07	14.31
Mean	12.41	17.04	9.64	
SEd	0.397	0.499	0.636	
CD(P=0.05)	0.845	1.064	1.356	

Table 5. Effect of INM on Transpiration rate (m mol m^{-2} s^{-1}) of *Dalbergia sissoo*

Treatment	Transpiration rate (m mol m-2 s-1)			
	6 MAP	12MAP	18MAP	Mean
T_1	2.18	5.32	2.20	3.23
T_2	3.21	4.98	2.97	3.72
T_3	3.32	5.74	3.01	4.02
T_4	4.56	6.31	3.45	4.77
T_5	4.35	5.66	3.71	4.57
T_6	4.93	5.36	3.38	4.56
Mean	3.76	5.56	3.12	
SEd	0.023	0.036	0.019	
CD(P=0.05)	0.050	0.076	0.041	

Analysis of chlorophyll content indicated significant difference among various INM treatments. Compared to untreated control, the INM treatments expressed higher chlorophyll a, b and total chlorophyll content. The values ranged between 0.919 mg $g^{-1}$and 1.960 mg g^{-1} in chlorophyll a, 0.713 mg g^{-1} and 0.943 mg g^{-1} in chlorophyll b and 1.636 mg $g^{-1}$and 2.908 mg g^{-1} in total chlorophyll content at 18 MAP. Among INM treatments, the integrated application of 125 % of STV (138:98:65 NPK kg ha^{-1}) + VAM (100 g $plant^{-1}$) + *Azospirillum* (50 g $plant^{-1}$) + Phosphobacteria (50 g $plant^{-1}$) + FYM (500 g $plant^{-1}$) (T_6) expressed significantly higher chlorophyll a, b and total chlorophyll content at 18 MAP and the lowest total chlorophyll content was observed in control (Table 3).

This might be ascribed due to the fact that the crop enjoyed better nutrition especially N from inorganic, organic and biofertilizer sources and hence enhanced chlorophyll 'a', 'b' and total chlorophyll content.

The present findings were in accordance with Latha *et al*. (1996) who reported that the application of N, P and K fertilizers to *Anacardium occidentale*, significantly affected the chlorophyll b content of leaves. Acharya (2003) reported that biofertilizers along with other organic and inorganic fertilizers could increase growth parameters, formation of new culms and chlorophyll content in *Bambusa bambos* plantation. Similarly the INM treatments could also supply *Dalbergia sissoo* with available form of nutrients in a continuous way, which reflected in high chlorophyll content in the leaves. Combined application of *Azospirillum* and Phosphobacteria enhanced the availability of P in the soil and VAM has mobilized the P from the soil to the plant. Nitrogen fixation by *Azospirillum* enhanced the nitrogen availability and VAM enhanced the root absorptive area network. This may have led to better chlorophyll content.

In the present study, a comparative estimation on ecophysiological behavior of *Dalbergia sissoo* at six INM treatment levels was carried out. The INM treatments imposed on the trees influenced the ecophysiological response with respect to stresses like drought, high temperature, acidity, high wind and other environmental factors.

Photosynthetic rate is a measure of productivity of tree and the mean photosynthetic rate was highest (14.31 µ mol m^{-2} s^{-1}) in 125 % of STV (138:98:65 NPK kg ha^{-1}) + VAM (100 g $plant^{-1}$) + *Azospirillum* (50 g $plant^{-1}$) + Phosphobacteria (50 g $plant^{-1}$) + FYM (500 g $plant^{-1}$) followed by 100 % of STV (110:78:52 NPK kg ha^{-1} + VAM (100g $plant^{-1}$) + Azospirillum (50g $plant^{-1}$) + Phosphobacteria (50 g $plant^{-1}$) + FYM (500 g $plant^{-1}$) (T_5) (14.06 µ mol m^{-2} s^{-1}) and the lowest mean photosynthetic rate of 10.50 µ mol m^{-2} $s^{-1}$was recorded in control (Table 4). With regard to transpiration rate at 18 MAP, the same treatment accounted for highest transpiration rate of 3.71 m mol m^{-2} s^{-1} followed by recommended dose of fertilizer (3.45 m mol m^{-2} s^{-1}). The lowest level of transpiration (2.20 m mol m^{-2} s^{-1}) was registered by control (Table 5). The mean performance in term of stomatal conductance of INM treatments revealed that stomatal conductance of 0.16 m molm^{-2} s^{-1} was the highest in 125 % of STV (110:78:52NPK kg ha^{-1}) + VAM (100 g

Table 6. Effect of INM on Stomatal conductance (m mol m^{-2} s^{-1}) of *Dalbergia sissoo*

Treatment	Stomatal conductance (m mol m^{-2} s^{-1})			
	6 MAP	12MAP	18MAP	Mean
T_1	0.09	0.19	0.13	0.14
T_2	0.11	0.22	0.09	0.14
T_3	0.13	0.18	0.08	0.13
T_4	0.08	0.21	0.12	0.14
T_5	0.12	0.23	0.11	0.15
T_6	0.13	0.20	0.14	0.16
Mean	0.11	0.21	0.11	
SEd	0.010	0.013	0.010	
CD(P=0.05)	0.022	0.027	0.021	

Table 7. Effect of INM on biomass production of *Dalbergia sissoo* at 18 MAP

Treatment	Leaf weight (kg tree^{-1})	Twigs weight (kg tree^{-1})	Branch weight (kg tree^{-1})	Utilizable wood weight (kg tree^{-1})	Root weight (kg tree^{-1})	Total biomass (kg tree^{-1})	Total dry weight (kg tree^{-1})
T_1	0.92	0.62	0.99	4.51	1.10	8.14	4.64
T_2	1.76	0.87	1.29	7.64	1.87	13.44	7.67
T_3	2.34	0.87	1.90	9.82	2.73	17.66	10.10
T_4	2.73	0.99	2.14	11.43	3.10	20.39	11.66
T_5	3.25	1.13	3.22	13.11	4.16	24.87	14.18
T_6	3.71	1.23	4.77	14.02	4.75	28.48	16.19
Mean	2.45	0.95	2.39	10.09	2.95	18.83	10.74
SEd	0.1521	0.0564	0.1681	0.2467	0.1238	1.1352	0.2524
CD(P=0.05)	0.3242	0.1202	0.3583	0.5259	0.2639	2.4196	0.5379

plant^{-1}) + *Azospirillum* (50 g plant^{-1}) + Phosphobacteria (50 g plant^{-1}) + FYM (500 g plant^{-1}) (T_6) and the lowest stomatal conductance of 0.13 m mol m^{-2} s^{-1} was recorded in 110:78:52 NPK kg ha^{-1} (T_3) (Table 6).

Increased photosynthetic rate under high fertilizer level could be because *Dalbergia sissoo* was supplied with available form of nutrients in a continuous way, which reflected in highest growth and spreading canopies, enabling maximum harnessing of solar radiation. Similar findings have been reported by Kao and Tsai (1999) who stated that an increase in nitrogen availability significantly increased the photosynthetic rate in salinity area grown seedlings of *Kandelia candel*. Increased transpiration rate under INM treated plants might be due to maximum exposure of all the plant parts to solar radiations thereby activating more photosynthesis and this might have resulted in higher transpiration rate in *D. sissoo*. Baranidharan *et al.* (2013) stated that among the various nutrient levels the highest net photosynthetic rate value of 6.61 and 6.76 µ mol m^{-2} s^{-1} and highest transpiration rate of 2.20 and 2.38 m mol m^{-2} s^{-1} was observed in 25 % more of fertilizer application over the soil test recommendation value of 93.75: 225: 100 of NPK kg ha^{-1} which was significantly superior over all other nutrient levels, in *Casuarina* species.

During 18 MAP, application of 125% of STV (138:98:65 NPK kg ha^{-1}) + VAM (100 g plant^{-1}) + *Azospirillum* (50 g plant^{-1}) + Phosphobacteria (50 g plant^{-1}) + FYM (500 g plant^{-1}) recorded the highest values for all the characters studied *viz.,* leaf weight (3.71 kg tree^{-1}), twig weight (1.23 kg tree^{-1}), branch weight (4.77 kg tree^{-1}), stem weight (14.02 kg tree^{-1}), root weight (4.75 kg tree^{-1}), total biomass (28.48 kg tree^{-1}) and total dry weight (16.19 kg tree^{-1}) followed by T_5. At the same time, the lowest values for all the traits were recorded in T_1. The variations in all the above traits observed among the treatments were statistically significant (Table 7).

Higher photosynthetic rate due to INM could also be a reason for higher production of leaf, twigs, branches, utilizable wood and root biomass. This is in line with Hunter (2000) who observed the above ground biomass and nutrient uptake of three tree species *viz., Eucalyptus camaldulensis, Eucalyptus grandis and Dalbergia sissoo* at three years of age. Application of fertilizer dose of 320: 30:100 kg NPK ha^{-1} at planting resulted in total dry weight averaging 45.3 tonnes/ha in both the *Eucalyptus* species while the *Dalbergia* had an average dry weight of just 7.6 tonnes.

Increased fertilizer application increased the growth of *D. sissoo* resulting in higher wood production. These results are in line with Bheemaiah (2004) who reported that the effect of irrigation and fertilizer application on the growth of Teak (*Tectona grandis*) in a sandy loam soil of low N, medium P and high K, wherein application of 300 g urea plant^{-1} had resulted in more volume growth (0.052 m^3 tree^{-1}), height (7.31 m) and DBH (0.114 m) at the age of five years after planting. Increase in total dry matter production of trees might be due to the synergistic role of *Azospirillum*, *Phosphobacteria* and VAM in combination with N, P_2O_5, K_2O and FYM which could supply the required nutrition to *Dalbergia sissoo* to put forth higher dry matter production. This is in accordance with the findings of Hulikatti and Madiwalar (2011) who conducted an experiment to study the influence of weeds and nutrient practices on the growth and nutrient uptake in *Acacia auriculiformis* trees.

CONCLUSION

The study conducted on the nutrient management practices of *Dalbergia sissoo* revealed that all the growth parameters, quality parameters such as chlorophyll content, photosynthetic rate, transpiration rate and stomatal conductance were found to be higher with the treatment T_6 which received 125% of STV 138:98:65 NPK kg ha^{-1} + VAM (100g plant^{-1}) + *Azospirillum* (50g plant^{-1}) + Phosphobacteria (50g plant^{-1}) + FYM (500g plant^{-1}). Soil test value based integrated application of organics along with inorganic fertilizers could increase the growth as well as dry matter production in clonal plants of *Dalbergia sissoo* during the initial growth stages especially during the first and second year of growth. The present study will help in arriving at possible juvenile adult correlations, if any in sissoo clones besides aiding in precision application of a mix of inorganic, organic and bio fertilizers through INM mode.

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