ISSN: 2278-5213

RESEARCH ARTICLE

Integrated nutrient management on the growth enhancement of *Dalbergia sissoo* Roxb. seedlings

R. Revathi[1], V. Mohan[2*] and M.N. Jha[3]
[1]Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam, Coimbatore, TN, India; [2]Forest Protection Division, Institute of Forest Genetics and Tree Breeding, Coimbatore; [3]Forest Research Institute, P.O. New Forest, Dehra Dun
mohan@icfre.org[*]; +91 9443426214

Abstract

Biofertilizers and biomanures are highly useful for afforestation and reclamation of degraded lands, mined overburdens and other problematic areas. Integrated Nutrient Management (INM) is a recently developed practice in agriculture where sustained high biomass production has become a vital necessity of the country. INM takes into account the optimizing performance of soil through augmenting chemical and biological properties of soil. Thus, a strong possibility exists in the field of forestry to boost biomass productivity per unit area per unit time by adopting INM practice. An attempt was made to determine the effect of inorganic fertilizers *i.e.,* macro (N, P and K) and micro nutrients (Fe, Zn, B and Mo) with biofertilizers such as N fixing bacteria (*Rhizobium*) and P mobilizing symbiotic fungi (AM fungi) and biomanures (leaf manures) in normal and alkaline soils on seedling growth of *Dalbergia sissoo.* It was observed that dual inoculation with biofertilizers (*Rhizobium* and AM) was impressive in improving the growth and biomass of Shisham under normal soil whereas in alkaline soil, blending of micronutrients with biofertilizers (*Rhizobium* + AM) had better growth and biomass.

Keywords: Biofertilizers, biomanures, integrated nutrient management, *Dalbergia sissoo*, *Rhizobium.*

Introduction

Forests, the key element of the terrestrial ecosystem are crucial for the well being of humanity. They provide foundations for life on earth through ecological functions, by regulating climate and water resources and by serving as habitats for plants and animals. They also furnish a wide range of essential goods such as food, fodder, fuel and medicines, in addition to opportunities for recreation, spiritual renewal and other services. However, in the recent past, this natural resource has been subjected to various pressures mainly biotic and abiotic pressures. According to the national forest policy, 1988, the area under forest/tree cover should be enhanced to 33% of the total land area. This can be achieved by rehabilitating the degraded forests and by promoting the plantation forestry. Plantation forestry was initiated mainly for the production of industrial raw materials as well as fuel wood and fodder.

Dalbergia sissoo Roxb., (Shisham) is a fairly large deciduous tree that occurs in the entire sub-himalayan tract of the Indus valley to Assam and also in the Himalayan valleys up to 1000 m and sometimes up to 1500 m. It grows gregariously in alluvial forest and on freshly exposed soils along roads, streams and landslips. It is an important multipurpose tree. The wood is valued for furniture and other utility and fancy items. It is extensively planted along the riverbanks, canal side, road side and as a shade tree in tea gardens and for rehabilitation of degraded lands.

It is amongst the principal tree species commonly recommended for afforestation programmes in dry regions for soil and water conservation. Shisham being of great economic and commercial value, this tree species was tried on some salt affected soils (Yadav and Singh, 1970). Singh *et al.* (1990) studied performance of Shisham in salt affected soils and found that higher concentration of neutral salts in the top 12 to 17 cm soil did not adversely affect the growth of plants. It is a strong light demander, frost hardy and the leaves are fed to cattle and are classed as medium to good fodder.

In recent years, use of biomanures and biofertilizers for the production of quality planting stock in forest nurseries is well-known. Biofertilizers are highly useful for afforestation and reclamation of degraded lands, mined overburdens and other problematic areas. Biofertilizers are biologically active products or microbial inoculants of bacteria, algae and fungi, which may help biological nitrogen fixation, phosphate solubilization and mobilization and help the plants to survive in waste lands and other problem soils. These biofertilizers also include organic fertilizers (biomanures), which are rendered in an available form due to the interaction of microorganisms or due to their association with plants. Integrated nutrient management is a recently developed practice in agriculture where sustained high biomass production has become a vital necessity of the country. INM takes in to account the optimizing performance of soil through augmenting chemical and biological properties of soil.

Thus, a strong possibility exists in the field of forestry to boost biomass productivity per unit area per unit time by adopting INM practice. The effective utilization of bioinoculants for crop will not only provide economic benefits but also improves and maintain the soil fertility and sustainability in natural soil ecosystem. Since, these bioresources represent a great diversity in chemical, physical and biological characteristics, their efficient use depend upon the particular forest ecological environment and also local availability. This may also provide an alternate for the use of costly fertilizers and help in afforestation programmes and reclamation of wastelands and other adverse sites. Tropical soils are either poor in phosphorus (P) or other essential nutrients or have an immobile form of P. In such condition, beneficial microorganisms can play an important role in improving the plant growth by increasing the supply to roots with mineral nutrients in the soil.

Each tree species favors a specific combination of beneficial microbes to flourish in its rhizosphere. This specific combination of beneficial microbes also improves the germination ability of seeds by reducing the seed dormancy through the production of growth promoting substances. Mycorrhizal fungi, nitrogen fixing bacteria and phosphobacteria are some of the bioinoculants (biofertilizers) which can serve as an important tool in forestry programme to improve the survival and growth of tree species. Inoculating nursery seedlings with selective bioinoculants (biofertilizer) holds promise for improving seedling quality, reducing transplanting period, out planting performances, increased resistance to root or soil borne diseases, parasitic nematodes and climatic stress. Also use of these beneficial microbes as bioinoculants (biofertilizers) would reduce the cost of chemical fertilizers involved in plantation programmes.

The effective utilization of bioinoculants for trees will not only provide economic benefits but also improve and maintain the soil fertility. Presently, different kinds of biofertilizers are being used in forestry for boosting the growth of tree seedlings in nursery. The role of biofertilizer has already been proved extensively in the field of annual crops, but information regarding its applicability in perennial crops or trees is scanty in India. However, in forestry, few research reports are available to demonstrate, that biofertilizers stimulate the growth (Rangarajan *et al*., 1987; Srinivas, 1987; Niranjan *et al.,* 1990); biomass (Huang *et al.,* 1985) and enhance the uptake of macro nutrients *viz.,* Nitrogen (N) (Manjunath *et al*., 1984; Chang *et al*., 1986); Phosphorus (P) (Dela Cruz *et al*, 1988); Potassium (K) (Huang *et al*., 1985; Merina Prem Kumari, 1991) and other micronutrients and thereby the survival rate of planted seedlings are increased. Application of several macro nutrients (N, P and K) and micro nutrients (Zn, Fe) can considerably improve tree growth and productivity (Sahu and Manhot, 1989).

Application of highly efficient biofertilizers will not only give desired benefits in terms of good seedling quality but also ensure out planting performance in the field and improve soil health which is essential for sustainable and eco-friendly forestry. This study was taken to determine the effect of inorganic fertilizers *i.e.,* macro (N, P and K) and micro nutrients (Fe, Zn, B and Mo) with biofertilizers such as N fixing bacteria (*Rhizobium*) and P mobilizing symbiotic fungi (AM fungi) in normal and alkaline soils on seedling growth of *D. sissoo.*

Materials and methods

Study area: Nursery experiments were conducted at Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore.

Seed collection and Rhizobium isolation: Seeds of *D. sissoo* were collected from a natural stand of Shisham at Tiruvannamalai, managed by the State Forest department, Government of Tamil Nadu. *Rhizobium* strains were isolated from nodules of *D. sissoo* seedlings and *Rhizobium* biofertilizer inoculum was mass produced and used for inoculation. The AM fungal inoculum, *Glomus fasciculatam* was isolated from the rhizosphere of *D. sissoo* plantation soils and mass produced at Forest Protection Division glass house of IFGTB, Coimbatore and maintained.

Soil collection: The soil (potting medium) needed for the study *viz.,* normal and alkaline soils collected from Coimbatore and Trichy respectively were used for conducting nursery experiment. The leaves of *Gliricidia sepium* were used as green leaf manure for the studies.

Experimental design: Two set of experiments were conducted with normal and alkaline soils. In normal soil three sets of potting mixtures were prepared. First set consisting of soil, sand and Farm yard manure (FYM) in the ratio of 2:1:1. The second set consisting of soil, sand in the ratio 2:1. Third set consisting of soil, sand and green leaf manure in the ratio of 2:1:1. Similarly in alkaline soil, three set of potting mixtures were prepared. The polythene bags of size 10 x 20 cm were filled with the above potting mixtures and chemical fertilizers (N, P and K) were added as per the treatment schedule.

Treatment schedule:

Major nutrients:

N: P_2O_5: K_2O	: 9:18:9 kg/1, 00,000 seedlings
Nitrogen as Urea	: 0.09 g N or 0.2 g urea/seedling
Phosphorus as single super phosphate	: 0.18 g P_2O_5 or 1.125 g SSP/seedling
Potassium as Murate of Potash	: 0.09 g K_2O or 0.15 g MOP/seedling
Gypsum	: 10 g/kg of alkaline soil

Micro nutrients:

Zinc as Zinc sulphate	: 5 ppm/seedling
Iron as Ferrous sulphate	: 5 ppm/seedling
Boron as Borax	: 2 ppm/seedling
Molybdenum as Sodium molybdate	: 2 ppm/seedling

Biofertilizers:
Rhizobium strain isolated from *D. sissoo* : 5 g/poly bag
AM fungal biofertilzer-*G. fasciculatum* : 10 g/poly bag

Treatment structure and experimental design:
(a) Normal soil:
Treatments:
Control (with NPK 9:18:9)
NPK + Zn
NPK + Fe
NPK + B
NPK + Mo
NPK + *Rhizobium*
NPK + *Rhizobium* + Zn
NPK + *Rhizobium* + Fe
NPK + *Rhizobium* + B
NPK + *Rhizobium* + Mo
NPK + AM
NPK + AM + Zn
NPK + AM + Fe
NPK + AM + B
NPK + AM + Mo
NPK + *Rhizobium* + AM
NPK + *Rhizobium* + AM +Zn
NPK + *Rhizobium* + AM + Fe
NPK + *Rhizobium* + AM + B
NPK + *Rhizobium* + AM + Mo
(b) Alkaline soil:
Treatments:
Control (with NPK (9:18:9) + Gypsum
NPK + Gypsum + Zn
NPK + Gypsum + Fe
NPK + Gypsum + B
NPK + Gypsum + Mo
NPK + Gypsum + *Rhizobium*
NPK + Gypsum + *Rhizobium* + Zn
NPK + Gypsum + *Rhizobium* + Fe
NPK + Gypsum + *Rhizobium* + B
NPK + Gypsum + *Rhizobium* + Mo
NPK + Gypsum + AM
NPK + Gypsum + AM + Zn
NPK + Gypsum + AM + Fe
NPK + Gypsum + AM + B
NPK + Gypsum + AM + Mo
NPK + Gypsum + *Rhizobium* + AM
NPK + Gypsum + *Rhizobium* + AM + Zn
NPK + Gypsum + *Rhizobium* + AM + Fe
NPK + Gypsum + *Rhizobium* + AM + B
NPK + Gypsum + *Rhizobium* + AM + Mo

Thus, there were 20 treatments in each set. The experimental design was factorial completely randomized design with five replications. The outer coat of seeds of *D. sissoo* were removed and sown in raised nursery beds. The seeds started to germinate from the 7th d onwards and continued up to 15 d. The germinated seedlings were pricked from the mother bed and transferred in polythene bags containing pot mixture with major nutrients (N, P and K).

Prior to pricking, biofertilizers were applied as per treatment schedule and 15 d old seedlings were transplanted. The poly bags were again filled with soil, and were maintained at field capacity. Micronutrients were applied after 30 d.

Biometric Observations: Observations were taken at initial and final stages of the experiment. The observation recorded were shoot length, root length, collar diameter, shoot dry weight and root dry weight after 10 months.

Statistical analysis: Growth parameters and analytical data obtained in the study were subjected to statistical analysis to determine the effects due to treatments (Panse and Sukhatme, 1967).

Results and discussion

Shoot length: The shoot length ranged from 43.50 cm to 110.1 cm in Normal soils, and from 22.60 cm to 101.3 cm in alkaline soils (Table 1). The effect of various treatments was found to be highly significant in both types of soils. Iron treatment significantly increased the shoot length to a maximum of 88.88 cm in P3 and 81.65 cm in P1 and 77.38 cm in P2 in normal soils. Dual inoculation with *Rhizobium* and AM, increased shoot length in both types of soil, in all the 3 potting mixtures and the values were 90.62 cm, 90.98 cm and 98.54 cm for P1, P2, and P3 respectively in normal soils whereas, in alkaline soils the shoot length was 78.96 cm, 41.76 cm and 86.18 cm in P1, P2 and P3 respectively. The interaction effect was highly significant on shoot length, maximum in P3 (110.1 cm) followed by P1 (97.2 cm) and P2 (95.4 cm) in normal soils, whereas in alkaline soils, the shoot length was highest in P1 (101.3 cm), followed by P3 (97.1 cm) and P2 (43.1 cm) (Table 2).

Root length: Significant variations were observed in root length due to different potting mixtures in both types of soil. Among different treatments, molybdenum treated plants recorded maximum root length in all the 3 potting mixtures (P1-37.78 cm, P2-38.40 cm, P3-49.03 cm) for Normal soils, and for Alkaline soils the values recorded are 27.08 cm, 18.43 cm, and 32.35 cm in P1, P2, P3 potting mixtures respectively (Table 3). Dual inoculation with biofertilizers increased the root length in all the 3 potting mixtures in both types of soil, and the values recorded were 45.55 cm, 39.82 cm, 52.32 cm in normal soils (P1, P2 and P3) and 26.66 cm, 19.38 cm 28.78 cm for alkaline soils in P1, P2 and P3 potting mixtures respectively. The interaction effect was found to be highly significant on both the soil types. The maximum root length recorded was 58.6 cm in normal soils and in alkaline soils it was 39.4 cm in P3 potting mixture (Table 4). Shoot length exhibited significant variations due to various treatments. Dual inoculation with biofertilizers increased the shoot and root lengths irrespective of different potting mixtures in both soil types, which are in conformity with the results of Islam and Ayanaba, (1981) in annual crops.

Table 1. Effect of inorganic and biofertilizers on shoot length in *Dalbergia sissoo* seedlings grown in normal soils.

Treatments	P1						P2						P3					
	Shoot length (cm)						Shoot length (cm)						Shoot length (cm)					
	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg
Control	43.50	66.40	71.40	63.20	59.20	60.74	56.50	62.30	58.00	59.30	54.00	58.02	59.90	54.00	80.40	77.70	47.40	63.88
Rhizobium	69.50	87.40	88.80	73.70	71.40	78.16	62.30	65.70	68.00	60.90	71.30	65.64	76.20	90.00	93.50	69.10	93.70	84.50
AM	83.50	67.30	72.10	61.20	85.40	73.90	76.30	71.80	88.10	74.20	72.40	76.56	88.20	87.00	81.70	92.10	90.00	87.80
Rhi + AM	85.20	88.50	94.30	87.90	97.20	**90.62**	84.50	88.90	95.40	93.90	92.20	**90.98**	91.20	96.40	99.90	95.10	110.10	**98.54**
Avg	70.43	77.40	**81.65**	71.50	78.30	75.86	69.90	72.18	**77.38**	72.08	72.48	72.80	78.88	81.85	**88.88**	83.50	85.30	83.68
	P			B			N			P x B			B x N		**P x N**			P x B x N
SEd	0.5110			0.5900			0.6597			1.0220			1.3194		1.1426			2.2853
CD (0.05)	1.0040**			1.1594**			1.2962**			2.0081**			2.5925**		2.2451**			4.4903**

Table 2. Effect of inorganic and biofertilizers on shoot length in *Dalbergia sissoo* seedlings grown in alkaline soils.

Treatments	P1						P2						P3					
	Shoot length (cm)						Shoot length (cm)						Shoot length (cm)					
	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg
Control	50.50	57.50	74.20	48.80	41.40	54.48	22.60	28.90	30.60	28.90	28.70	27.94	34.40	50.20	56.80	52.90	45.60	47.98
Rhizobium	61.60	61.80	88.90	55.90	58.20	65.28	33.00	33.50	35.20	32.20	36.10	34.00	43.20	56.70	61.50	55.70	58.40	55.10
AM	58.90	57.60	63.60	60.90	81.30	64.46	35.30	35.30	35.60	35.00	35.00	35.24	48.90	53.90	56.50	58.70	79.00	59.40
Rhi + AM	72.80	70.00	72.00	78.70	101.30	**78.96**	39.50	41.70	41.80	42.70	43.10	41.76	**76.50**	97.10	91.60	83.40	82.30	**86.18**
Avg	60.95	61.73	**74.68**	61.08	70.55	65.80	32.60	34.85	**35.80**	34.70	35.73	34.74	50.75	64.48	**66.60**	62.68	66.33	62.17
	P			B			N			P x B			B x N		**P x N**			P x B x N
SEd	0.4496			0.5191			0.5804			0.8992			1.1608		1.0053			2.0107
CD (0.05)	0.8834**			1.0200**			1.1404**			1.7668**			2.2809**		1.9753**			3.9507**

Table 3. Effect of inorganic and biofertilizers on root length in *Dalbergia sissoo* seedlings grown in normal soils.

Treatments	P1						P2						P3					
	Shoot length (cm)						Shoot length (cm)						Shoot length (cm)					
	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg
Control	28.00	28.00	21.60	26.60	28.90	26.05	15.70	24.50	25.70	30.20	27.00	24.62	42.30	39.80	55.90	43.10	29.70	42.16
Rhizobium	46.90	32.80	28.30	27.80	29.00	33.95	27.20	28.80	29.80	27.10	39.70	30.52	30.70	39.60	41.00	30.30	58.60	40.04
AM	28.00	27.70	49.40	53.70	50.70	39.70	27.40	39.00	35.50	27.60	39.70	33.84	41.40	45.30	41.00	41.40	56.90	45.20
Rhi + AM	40.80	56.20	48.20	37.00	42.50	**45.55**	42.80	36.70	40.30	32.10	47.20	**39.82**	51.70	51.40	55.90	51.70	50.90	**52.32**
Avg	35.93	36.18	36.88	36.28	**37.78**	36.31	28.28	32.25	32.83	29.25	**38.40**	32.20	41.53	44.03	48.45	41.63	**49.03**	44.93
	P			B			N			P x B			B x N		**P x N**			P x B x N
SEd	0.4076			0.4706			0.5262			0.8152			1.0524		0.9114			1.8228
CD (0.05)	0.8008**			0.9247**			1.0339**			1.6017**			2.0678**		1.7908**			3.5816**

Table 4. Effect of inorganic and biofertilizers on root length in *Dalbergia sissoo* seedlings grown in alkaline soils.

Treatments	P1						P2						P3					
	Shoot length (cm)						Shoot length (cm)						Shoot length (cm)					
	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg
Control	17.50	28.70	25.00	22.20	21.70	23.02	15.20	16.10	16.80	11.20	19.20	15.70	17.70	20.30	31.70	18.70	15.00	20.68
Rhizobium	25.00	20.40	30.90	30.31	25.20	26.36	15.10	15.50	16.60	19.60	15.90	16.54	27.70	25.10	30.50	30.50	36.40	30.04
AM	23.90	24.50	24.00	25.30	25.90	24.72	15.30	16.30	19.80	18.00	17.20	17.32	27.20	23.10	28.50	24.70	39.40	28.58
Rhi + AM	30.00	21.10	25.60	21.10	35.50	**26.66**	16.30	18.20	19.70	18.20	21.40	**18.76**	24.00	30.50	26.20	24.60	38.60	**28.78**
Avg	24.10	23.68	26.38	24.73	**27.08**	25.19	15.48	16.53	18.23	16.75	**18.43**	17.08	24.15	24.75	29.23	24.63	**32.35**	27.02
	P			B			N			P x B			B x N		**P x N**			P x B x N
SEd	0.3947			0.4558			0.5096			0.7895			1.0193		0.8827			1.7654
CD (0.05)	0.7756**			0.7756**			1.0013**			1.5513**			2.0027**		1.7344**			3.4688**

Table 5. Effect of inorganic and biofertilizers on collar diameter in *Dalbergia sissoo* seedlings grown in normal soils.

Treatments	P1						P2						P3					
	Collar diameter (cm)						Collar diameter (cm)						Collar diameter (cm)					
	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg
Control	0.76	1.04	1.22	1.18	1.16	1.07	0.40	0.55	0.78	0.69	0.60	0.60	0.88	0.95	1.21	0.81	1.19	1.01
Rhizobium	1.27	1.15	1.31	1.09	1.28	1.22	0.95	1.09	1.30	1.16	1.29	1.16	1.33	0.99	1.26	1.04	1.02	1.13
AM	1.35	1.22	1.41	1.30	1.29	1.32	1.01	1.06	1.29	1.24	1.19	1.16	1.46	1.28	1.66	1.49	1.39	1.46
Rhi + AM	1.47	1.49	1.61	1.51	1.57	**1.53**	1.19	1.42	1.89	1.36	1.62	**1.50**	1.52	2.21	2.33	2.12	2.31	**2.10**
Avg	1.21	1.22	**1.39**	1.27	1.33	1.28	0.89	1.03	**1.31**	1.11	1.18	1.10	1.30	1.36	**1.61**	1.36	1.48	1.42
	P			B			N			P x B			B x N		**P x N**			P x B x N
SEd	0.003			0.004			0.004			0.006			0.008		0.007			0.015
CD (0.05)	0.006**			0.007**			0.008**			0.013**			0.017**		0.015**			0.030**

With respect to nutrient addition, Iron treatment enhanced the shoot length in both soil types with different potting mixtures, which might be due to the presence of phosphorus. The potting mixture with green leaf manure exhibited maximum shoot and root lengths, as reported by Singh *et al.* (1988), due to addition of vermicompost and mulching which has enhanced the shoot and root lengths and is in consonance with earlier workers too (Gupta, 1991; Paul *et al.,* 1998). Shoot and root lengths were significantly influenced by biofertilizers and nutrient addition in alkaline soils. *Dalbergia sissoo* being capable of producing wider root spread and deep penetration ameliorates sodic soils more efficiently (Garg and Jain, 1996) and is similar to the reports of Singh *et al.* (1990) and Patil *et al.* (1996), where absence of kankar pan and due to addition of gypsum as an amendment would have decreased the pH in the upper layer as a result of increased organic carbon as reported by Gill *et al*. (1987) in *Prosopis juliflora* and *Dalbergia sissoo* and it has performed well in saline and high water table condition which might be due to increased organic carbon due to addition of gypsum (Yadav and Sngh, 1970; Singh *et al.,* 1990, Tomar, 1997).

Collar diameter

The different nutrient treatment produced significant variation in collar diameter in both types of soil. With Normal soils, Iron treatment significantly enhanced the collar diameter which recorded 1.39 cm in P1, 1.31 cm in P2 and 1.61 cm in P3 (Table 5). In Alkaline soils, similar trend was observed with collar diameter and the values were 0.92 cm in P1, 0.65 cm in P2 and 1.10 cm in P3. With respect to dual inoculation of bio-fertilizers with *Rhizobium* and AM increased the collar diameter and the mean values were 1.53 cm, 1.50 cm, and 2.10 cm for normal soils, and 1.10 cm, 0.73 cm and 1.18 cm for alkaline soils, maximum in P3 potting mixture. The interaction was found to be highly significant and the collar diameter varied from 0.4 cm to 2.33 cm in Normal soils and 0.31 cm to 1.41 cm in Alkaline soils (Table 6). Iron application had a pronounced effect on seedlings collar diameter. On comparing the microbial inoculants, combined application of *Rhizobium* and AM was superior to all other treatments, which were in conformity with the findings of Gupta (1990). The interaction effect of micro nutrients and bio-fertilizers was superior in registering maximum collar diameter irrespective of potting mixtures, which might be due to the presence of phosphorus mobilizing symbiotic group of AM fungi and a similar trend was observed by Gurumurthy *et al.* (1999) in Shisham, and by Sumana and Bagyaraj (1998) in *Dalbergia latifolia.* Iron treatment enhanced the collar diameter, in all the three potting mixtures under both soil types, which might be due to nitrogen fixation which has enhanced collar diameter and according to Richards (1990), iron held with molybdenum in the cofactor cluster of larger protein responsible for binding and reduction of di-nitrogen where the increased nitrogen enhanced collar diameter.

Collar diameter was maximum with potting mixture having soil, sand and green leaf manure, which might be due to the addition of organic matter in surface soil, and the available N and P in surface and sub surface soil (Totey *et al.,* 1989) and also increased dry matter production by green manures when compared to FYM (Russell, 1975). Similar results were obtained by Murriah *et al.* (1991) when green leaf manure improved diameter of mahagony seedlings.

Shoot dry weight

The results revealed that application of nutrients and biofertilizers significantly increased the shoot dry weight under both types of soils in all the 3 potting mixtures. The shoot dry weight ranged from 35.27 g to 87.27 g in normal soils, and from 15.75 g to 30.53 g in alkaline soils (Table 7). With reference to the nutrient addition, Iron significantly increased the shoot dry weight in 3 potting mixtures (63.48 g, 56.84 g and 71.09 g) in normal soil, and in alkaline soil mean shoot dry weight was 21.09 g, 20.25 g and 25.93 g in P1, P2 and P3 potting mixtures respectively (Table 8). Dual inoculation of biofertilizers significantly enhanced the shoot dry weight in both the soil types and the mean values recorded were 68.94 g 60.32 g, 79.50 g for normal soils and for alkaline soils the mean values were 24.57 g, 21.49 g and 28.47 g, in P1, P2 and P3 potting mixtures respectively. The interaction effect was found to be highly significant, the maximum recorded by normal soil with green leaf manure potting mixture (87.27 g) and for alkaline soil, it was 30.53 g and lowest in potting mixtures with soil and sand (35.27 g) in Normal soils and with soil, sand and FYM (15.75 g) in Alkaline soils.

Root dry weight

The results revealed that the various nutrient applications significantly influenced the root dry weight in both the soil types. The root dry weight varied from 6.48 g, to 45.40 g, in Normal soils and from 6.44 g to 18.39 g in Alkaline soils (Table 9). Molybdenum application significantly increased the root dry weight in 3 potting mixtures in both soil types followed by Iron treatment. The mean values recorded were 26.44 g, 16.12 g, and 37.34 g in normal soils with Molybdenum treatment. Similar trend was observed in alkaline soils in which root dry weight of molybdenum treated seedlings recorded 10.33 g (P1), 9.38 g (P2), 15.60 g (P3), in different potting mixtures respectively. With reference to biofertilizers inoculation, dual inoculation recorded maximum root dry weight (30.92 g for P1, 17.23 g for P2, 41.30 g for P3) in normal soils and (11.40 g for P1, 10.13 g for P2 16.67 g for P3) in alkaline soils. The interaction effect was found to be highly significant in both the soil types, maximum root length in P3 potting mixture with values 45.4 g followed by P1 (34. 26 g) and P2 (18.74 g) in normal soils. In alkaline soils also, similar trend was observed maximum in P3 (18.39 g) followed by P1 (13.31 g) and P2 (10.78 g) (Table 10).

Table 6. Effect of inorganic and biofertilizers on collar diameter in *Dalbergia sissoo* seedlings grown in alkaline soils.

Treatments	P1						P2						P3					
	Collar diameter (cm)						Collar diameter (cm)						Collar diameter (cm)					
	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg
Control	0.40	0.45	0.54	0.52	0.47	0.48	0.31	0.35	0.46	0.39	0.44	0.39	0.33	0.46	0.57	0.42	0.53	0.46
Rhizobium	0.72	0.77	0.93	0.86	0.83	0.82	0.52	0.58	0.59	0.68	0.63	0.60	0.62	0.84	1.09	0.97	0.93	0.89
AM	0.66	0.77	0.94	0.87	0.80	0.81	0.56	0.64	0.71	0.75	0.71	0.67	0.82	0.82	1.41	1.02	0.97	1.01
Rhi + AM	0.94	1.02	1.25	1.19	1.11	**1.10**	0.62	0.68	0.85	0.71	0.77	**0.73**	1.03	1.19	1.34	1.13	1.23	**1.18**
Avg	0.68	0.75	**0.92**	0.86	0.80	0.80	0.50	0.56	**0.65**	0.63	0.64	0.60	0.70	0.83	**1.10**	0.88	0.91	0.89
	P			B			N			P x B			B x N		**P x N**			P x B x N
SEd	0.0019			0.0022			0.0024			0.0038			0.0049		0.0042			0.0085
CD (0.05)	0.0037**			0.0043**			0.0048**			0.0075**			0.0096**		0.0083**			0.0167**

Table 7. Effect of inorganic and biofertilizers on shoot dry weight in *Dalbergia sissoo* seedlings grown in normal soils.

Treatments	P1						P2						P3					
	Shoot dry weight (g/seedling)						Shoot dry weight (g/seedling)						Shoot dry weight (g/seedling)					
	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg
Control	45.25	58.19	57.23	56.43	59.24	55.27	35.27	52.99	55.00	50.13	56.43	49.96	61.23	62.94	64.13	60.08	53.86	60.45
Rhizobium	60.48	59.34	63.36	62.07	61.15	61.28	51.49	49.25	53.47	45.16	51.03	50.08	62.44	62.59	61.87	63.30	73.02	64.64
AM	61.00	60.55	62.10	64.16	63.21	62.20	58.05	52.48	56.80	50.72	53.29	54.27	65.14	58.06	71.07	69.29	73.91	67.49
Rhi + AM	62.18	72.06	71.23	69.15	70.10	**68.94**	59.02	59.30	62.07	61.26	59.95	**60.32**	75.41	81.01	87.27	73.58	80.24	**79.50**
Avg	57.23	62.53	**63.48**	62.95	63.43	61.92	50.96	53.50	**56.84**	51.82	55.18	53.66	66.05	66.15	**71.09**	66.56	70.26	68.02
	P			B			N			P x B			B x N		**P x N**			P x B x N
SEd	0.0625			0.0722			0.0807			0.1251			0.1615		0.1399			0.2798
CD (0.05)	0.1229**			0.1419**			0.1587**			0.2458**			0.3174**		0.2749**			0.5498**

Table 8. Effect of inorganic and biofertilizers on shoot dry weight in *Dalbergia sissoo* seedlings grown in alkaline soils.

Treatments	P1						P2						P3					
	Shoot dry weight (g/seedling)						Shoot dry weight (g/seedling)						Shoot dry weight (g/seedling)					
	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg
Control	16.39	16.73	15.75	17.31	17.78	16.79	17.27	17.06	18.47	17.45	18.16	17.68	21.32	23.05	23.59	21.82	22.33	22.42
Rhizobium	18.43	18.89	20.19	18.25	19.49	19.05	18.65	18.97	19.70	19.13	19.63	19.22	24.13	23.43	24.52	23.78	24.21	24.01
AM	17.58	18.65	23.20	18.89	19.20	19.50	19.38	19.40	20.59	20.15	20.39	19.98	24.52	24.79	25.09	24.90	24.35	24.73
Rhi + AM	23.45	24.20	25.23	24.69	25.29	**24.57**	20.94	21.30	22.25	21.38	21.57	**21.49**	26.82	28.26	30.53	27.39	29.36	**28.47**
Avg	18.96	19.61	**21.09**	19.79	20.44	19.98	19.06	19.18	**20.25**	19.53	19.94	19.59	24.19	24.89	**25.93**	24.47	25.06	24.91
	P			B			N			P x B			B x N		**P x N**			P x B x N
SEd	0.0123			0.0142			0.0159			0.0246			0.0318		0.0275			0.0551
CD (0.05)	0.0242**			0.0279**			0.0312**			0.0484**			0.0625**		0.0541**			0.1082**

Table 9. Effect of inorganic and biofertilizers on root dry weight in *Dalbergia sissoo* seedlings grown in normal soils.

Treatments	P1						P2						P3					
	Root dry weight (g/seedling)						Root dry weight (g/seedling)						Root dry weight (g/seedling)					
	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg
Control	11.75	13.59	15.17	14.15	16.19	14.17	6.48	11.11	12.10	10.07	15.25	11.00	16.25	23.90	28.00	20.49	35.06	24.74
Rhizobium	17.49	22.42	21.11	20.25	25.16	21.29	17.25	12.20	13.07	13.90	14.43	14.17	38.32	30.07	24.21	20.07	28.97	28.32
AM	18.42	23.22	26.19	24.29	30.17	24.46	16.13	14.96	15.22	15.47	16.07	15.57	39.04	33.40	36.08	35.30	39.92	36.75
Rhi + AM	23.23	31.36	33.41	32.35	34.26	**30.92**	18.93	15.57	16.11	16.81	18.74	**17.23**	34.33	41.58	43.28	41.94	45.40	**41.30**
Avg	17.72	22.65	23.97	22.76	**26.44**	22.71	14.70	13.46	14.13	14.06	**16.12**	14.49	31.98	32.23	32.89	29.45	**37.34**	32.78
	P			B			N			P x B			B x N		**P x N**			P x B x N
SEd	0.0390			0.0450			0.0503			0.0780			0.1007		0.0872			0.1744
CD (0.05)	0.3427**			0.1713**			0.1978**			0.0153**			0.0989**		0.0885**			0.0766**

Table 10. Effect of inorganic and biofertilizers on root dry weight in *Dalbergia sissoo* seedlings grown in alkaline soils.

Treatments	P1						P2						P3					
	Root dry weight (g/seedling)						Root dry weight (g/seedling)						Root dry weight (g/seedling)					
	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg	Con	Zn	Fe	B	Mo	Avg
Control	7.84	7.96	8.31	8.27	6.67	7.81	6.44	6.74	7.13	7.40	7.77	7.09	10.11	10.44	11.09	10.85	11.68	10.83
Rhizobium	7.58	7.76	8.41	8.48	11.24	8.69	8.25	8.54	8.79	9.02	9.18	8.75	12.44	12.69	12.85	13.14	15.58	13.34
AM	9.12	9.52	10.02	9.76	11.41	9.97	8.45	9.30	9.64	9.46	9.80	9.33	12.74	13.61	14.49	15.19	16.77	14.56
Rhi + AM	10.05	10.19	13.31	11.44	12.01	**11.40**	9.13	10.03	10.25	10.45	10.78	**10.13**	14.42	17.57	16.76	16.23	18.39	**16.67**
Avg	8.65	8.86	10.01	9.49	**10.33**	9.47	8.07	8.65	8.95	9.08	**9.38**	8.83	12.43	13.58	13.80	13.85	**15.60**	13.85
	P			B			N			P x B			B x N		**P x N**			P x B x N
SEd	0.0126			0.0146			0.0163			0.0253			0.0327		0.0283			0.0567
CD (0.05)	0.0249**			0.0287**			0.0321**			0.0498**			0.0643**		0.0557**			0.1115**

Dry matter production of shoot and root manifested a progressive increase with various levels of micronutrients and biofertilizers application. With reference to biofertilizers treatment, dual inoculation with *Rhizobium* and AM fungi enhanced the shoot and root dry weights. This is in conformity with the reports of Diatloff (1973); Sanginga *et al.* (1986)*;* Dela Cruz *et al.* (1988) and Nish *et al.* (1999). The synergistic effect of the two symbionts on growth of *Leucaena leucocephala* was also experienced by Manjunath and Bagyaraj (1986). Mohan (2000) reported that the local AM fungal isolate *Glomus fasciculatum* performed better in increasing plant height and shoot and root biomass than other isolates on the seedlings of *Prosopis cineraria* and *P. juliflora* in arid zone soils of Rajasthan. AM fungi inoculated seedlings of *Cordia myxa*, *Artocarpus integer*, *Dalbergia sissoo, Pongamia pinnata, Mangifera indica* and *Alstonia* spp. performed better in terms of shoot height, root height and biomass (Srivastava *et al.,* 2001). Manoharan *et al.* (2010) investigated the effect of AM fungus, *Glomus mosseae* on growth and physiology of *Erythrina variegata* grown in sandy loam soil with four water stress levels. They found that AM fungal inoculated plants had significantly higher plant biomass, chlorophyll (a and b), carotenoids and protein content in shoots than control plants. Iron treatment enhanced the shoot dry weight in both soil types with various potting mixtures, which might be due to general dose of 'P' fertilizer application, which is in conformity with reports of Thompson (1990). Root dry weight was maximum in molybdenum treated soils, and similar trend was observed by Aziz and Habte (1988). Pelwan *et al.* (1987) found significant interaction between phosphorus and molybdenum for basal diameter of *Leucaena leucocephala.* The dry matter production was maximum with potting mixture of green leaf manure, which is in consonance with earlier findings made by Russell (1975); Singh *et al.* (1988) and Murriah *et al.* (1991). Significant correlation was observed between shoot dry weight and available N, P, K and Mo, also with root dry weight. The dry matter production was maximum in alkaline soils with potting mixture due to presence of green leaf manure and is similar to the findings of Singh *et al.* (1988) in poplars due to addition of poplar leaf litter to alkali soils.

Dual inoculation with biofertilizers (*Rhizobium* and AM) was impressive in improving the growth attributes like shoot length, root length, collar diameter and shoot and root biomass in Shisham under normal soils. With respect to organic fertilizer, the potting mixture with green leaf manure had a pronounced effect in enhancing the growth parameters like shoot length, root length, collar diameter and shoot and root biomass. The magnitude of increase was 12.6, 33.7, 24.2 and 30.9% respectively. With reference to the inorganic fertilizers, among the micronutrients, molybdenum treatment enhanced the root length and root dry weight and Iron treatment has enhanced the shoot length, shoot dry weight and collar diameter.

The growth parameters were positively and significantly influenced by soil available nitrogen, phosphorus, potassium and molybdenum alone whereas, with other nutrients, it was observed to be non-significant. Among the potting mixtures, the potting mixture with green leaf manure alone was influenced by the treatment combination, while the other two potting mixtures even though were influenced by the different treatments, there was no much difference between the potting mixture with soil: sand: FYM and soil: sand. Under alkaline soil condition the blending of micronutrients, with biofertilizers (*Rhizobium* + AM) was reflecting upon the shoot length, root length, collar diameter, shoot and root biomass. Dual application of biofertilizers (*Rhizobium* + AM) proved its superiority in recording highest shoot length, root length, collar diameter, shoot and root dry weights. With respect to micronutrients, molybdenum treatment had an excellent effect on root length and root dry weight, and iron treatment enhanced the shoot length, collar diameter and shoot dry weight irrespective of potting mixtures proving its superiority over other nutrients.

However, the potting mixture with green leaf manure had a pronounced effect on the growth of Shisham. It may be concluded that the trio-combination and judicious use of inorganic fertilizers (Macro nutrients and micro nutrients) with biofertilizers like *Rhizobium* and AM proved to be the best recommendation to enhance the seedling growth and biomass. The species evaluated on two types of soil revealed that it was best performing under Normal soils when compared to alkaline soils, but it can be grown under alkaline soils, with proper amendment both under nursery conditions and in degraded lands. With respect to potting mixture studies, potting mixture with green leaf manure, revealed its greatness in growth of seedlings thus expressing its superiority over other potting mixtures.

Conclusion

In this study, effect of inorganic fertilizers *i.e.,* macro (N, P and K) and micronutrients (Fe, Zn, B and Mo) with biofertilizers such as N fixing bacteria (*Rhizobium*) and P mobilizing symbiotic fungi (AM fungi) in normal and alkaline soils on seedling growth of *D. sissoo* was determined. It was observed that Pot mixture with soil, sand and green leaf manure enhanced the shoot length, root length, collar diameter, shoot and root dry weights. Among different inoculations, dual inoculation of biofertilizers (*Rhizobium* + AM) with micronutrients enhanced the shoot length, root length, collar diameter, shoot and root dry weights in all the 3 pot mixtures. It was also recorded that Iron treatment enhanced the shoot length; collar diameter and shoot dry weight in all the 3 potting mixtures. In general, normal soil proved to be superior when compared to alkaline soil in enhancing the growth of *D. sissoo* seedlings.

Acknowledgements

The authors are highly grateful to the Director, IFGTB for providing all the facilities and encouragement for carrying out this study.

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