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SUSTAINABLE QUALITY SEEDLING PRODUCTION OF NITROGEN FIXING TREE (NFT) SPECIES USING ORGANIC MANURES : A REVIEW

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ABSTRACT

Organic manures, derived from plant and animal residues, are increasingly recognized as sustainable components of nursery media for the production of high-quality seedlings of nitrogen fixing tree (NFT) species. Conventional nursery media often exhibit poor structural stability, low nutrient availability, and reduced microbial activity, resulting in inferior seedling growth and establishment. This review hypothesizes that incorporation of organic manures in suitable media combinations significantly enhances seedling growth, biomass accumulation, nutrient availability, and seedling quality indices compared to unamended nursery soil. Relevant literature published from 2002 to 2024 on NFT species was critically analysed, emphasizing variations in organic manure type, mixture ratio, and nursery media composition. The reviewed studies demonstrated that media combinations such as soil + sand + vermicompost (1:1:1), soil + FYM (1:3), soil + sand + goat manure (2:1:1), and soil + sand + vermicompost (2:1:2) consistently improved seedling height, collar diameter, root growth, biomass accumulation, survival percentage, Seedling Vigour Index, and Dickson Quality Index in species including *Casuarina equisetifolia*, *Dalbergia sissoo*, *Albizia lebbeck*, *Albizia procera*, *Pongamia pinnata*, *Prosopis cineraria*, and *Acacia auriculiformis*. Vermicompost and FYM exhibited comparatively superior performance over other organic amendments due to their balanced nutrient supply, improved water-holding capacity, and stimulation of beneficial microbial activity. Oilseed cakes such as karanj cake and neem cake also enhanced nodulation and biomass production in *Dalbergia* species. Synergistic effects were frequently observed when organic manures were combined with soil and sand in optimized ratios. Overall, organic manure-amended nursery media provide an eco-friendly, cost-effective, and efficient strategy for producing vigorous and field ready NFT seedlings for sustainable forestry, afforestation, and ecological restoration programmes.

***Keywords* :** FYM, nitrogen fixing trees, nursery media, organic manure, seedling quality.

Introduction

The word 'Manure' is derived from the French term *manoeuvre* which literally means 'to work with hand' and also from the Middle English term *manuren* which means to cultivate land. With due course of time, the word manure included any method applied necessary to improve the properties of soil (Mani, 2011). Organic manures are the organic materials originated from plant, animal and human residues comprising plant nutrients in complex organic forms and in relatively smaller concentrations. They may be broadly classified as 1. Bulky organic manures *e.g.* Farm Yard Manure (FYM), green manure, compost and crop residues; and 2. Concentrated organic manures which may be derived from plant sources like mustard oilcake, neem oilcake, karanj oilcake, *etc.* or derived from animal sources like bone meal, meat meal, hoof meal, *etc*. Concentrated organic manures are supplied in lower does in the soil because they contain relatively higher proportion of one or more of the higher quantities of plant nutrients like Nitrogen (N), Phosphorus (P) and Potassium (K). On the contrary, bulky organic manures are applied in voluminous dose while supplying plant nutrients in relatively smaller quantities (Goswami *et al*,. 2012).

Organic manures play a key role in augmenting soil as depicted in figure 1. It helps to imrpove (i) physical properties such as soil aggregation, aeration, water holding capacity and permeability; and (ii) chemical properties like enhancing cation exchange capacity of soil, increasing buffer capacity of soil, improving nutrients solubility or availability, altering soil salinity, sodicity, pH and increasing P absorption efficiency resulting in luxuriant growth of plants; and (iii) biological properties like stimulating microbial activity in the soil (Suhartatik and Sismiyati, 2000; Alabadan *et al.,* 2009). Traditionally soil has been utilized as a growing media for seedlings establishment and growth however, when the soil is used alone *i.e.* without any organic amendments, it tends to be of poor quality and more prone to root-knot infection by nematodes or root rotting diseases (Egunjobi and Ekundare, 1981). Addition of organic manures into the soil help in the slow and steady release of many vital nutrient elements which nourishes the beneficial bacteria to provide minerals in available form to the plants (Erin, 2007). The manures obtained from different types of animal contain nutrients in varied proportions. Generally, poultry manure is having higher N and P content and lower K content in comparison to pig, sheep and horse manure (Therios, 1996). On the other hand, cow manure is a rich source of N, Magnesium (Mg), Organic carbon (C) and Calcium (Ca) (Adegunloye *et al.*, 2007).

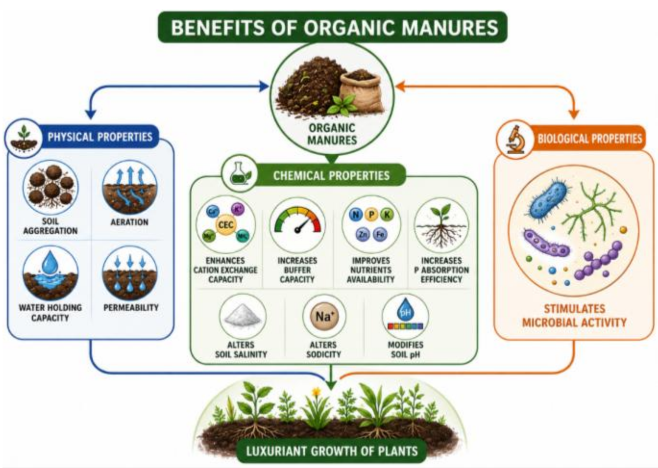

Fig. 1 : Benefits of organic manures on soil properties for enhancing plant growth

Nitrogen Fixing Trees and their Importance in Soil Improvement

Fabaceae is widely recognized as a plant family whose members commonly form symbiotic relationships with beneficial bacteria in their roots developing specialized structures called nodules, where the bacterial partners convert atmospheric nitrogen into ammonia, a form that can be readily utilized by plants (Wang, *et al.*, 2012). Nitrogen (N_2) Fixing Trees (NFT) are those which forms symbiotic relationship with nodule forming *Rhizobium* bacteria or actinomycetes of the *Frankia* genus (Dwivedi, 1992). Over 650 species (majority by Leguminosae) of trees are known to be fixing atmospheric nitrogen (NFTA, 1989). In case of degraded soils, it is suggested to introduce 90% of initial planting of NFT (pioneer species) and 10% of planting of overstory species having long-term canopy to improve the damaged soil quickly (Madivalar and Raj, 2014). The roots of tropical leguminous trees form nitrogen fixing nodules with fast growing strains belonging to genus *Rhizobium* and slow growing strains belonging to genus *Bradyrhizobium* (Elkan, 1984). Leguminous trees like *Leucaena leucocephala* or *Sesbania grandiflora* nodulates with *Rhizobium* only, while *Acacia mearnsii* or *A. albida* nodulates only with *Bradyrhizobium.* In addition to these two groups of leguminous trees, there is a third group comprising trees like *Acacia seyal,* which forms nodulation with both *Rhizobium* and *Bradyrhizobium* (Nair, 1993). Nitrogen fixing tree species beside fixing the atmospheric nitrogen offer a variety of uses such as provision of firewood and charcoal, fodder, timber and poles, enhancing soil fertility, uses in windbreaks, alley farming, homegardens, live fences and hedges, improved fallow and land reclamation (Madivalar and Raj, 2014).

SWOT Analysis of Organic Manures

The use of organic manures as growing media for the production of high-quality seedlings of nitrogen fixing trees is crucial and addresses the need for sustainable and ecofriendly practices. Organic manures not only result in enhancement of seedling quality in terms of better root-shoot ratio, sturdiness quotient, volume index, seedling quality index and seedling vigour index but also helps in the quick establishment of nursery raised seedlings in the field. The SWOT analysis for the use of organic manures for production of quality seedlings of nitrogen fixing tree species is shown in the figure 2 which specifies, more strength and opportunities in comparison to weakness and threat. Organic manure is a more effective medium for the production of high-quality seedlings of nitrogen fixing tree species, so this paper justifies its use as a viable alternative in seedling production for afforestation and reforestation efforts.

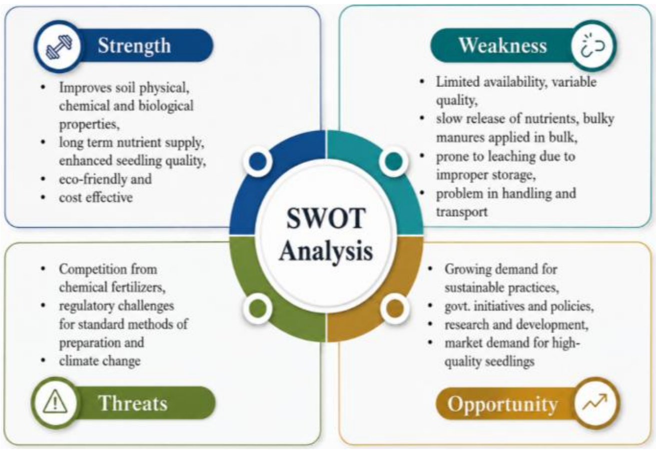

Fig. 2 : SWOT Analysis for the use of organic manures for production of quality seedlings of nitrogen fixing tree species

Organic manures in production of quality seedling of timber yielding nitrogen fixing tree species

Production of high-quality seedlings of timber yielding nitrogen fixing trees is essential to meet the increasing demand for high end timber uses like furniture, cabinet, carving, carpentry, turnery, heavy duty construction materials, poles, pilings, ship and house building, railway sleepers, joinery, canoe, flooring and agricultural implements. The influence of organic manures in production of quality seedling of timber yielding nitrogen fixing tree species is depicted in Table 1. Mahto *et al.* (2007) analyzed the effect of different de-oiled seed cakes as plant nutrient source on the growth and biomass production of *Dalbergia sissoo* seedlings. The results showed that all the de-oiled cakes gave better results in all the parameters than the control. The per cent increase in shoot length, collar diameter, root length, number of leaflets, leaflet area, nodule number and biomass production ranged from 3.59 to 22.13 %, 11.53 to 65.4 %, 21.5 to 76.5 %, 1.38 to 68.48 %, 1.68 to 69.07 %, 69.96 to 180.18 % and 20.0 to 50.43 % respectively. They suggested superior seedling growth and biomass attributes in the order of karanj cake > groundnut cake > neem cake > linseed cake > mahua cake > mustard cake on the basis of their performance. Kumar *et al.* (2014) recorded the highest seedling height (16.33 cm), collar diameter (0.36 cm), root length (4.74 cm), number of root nodules (23.33) and leaflets per plant (47.17), root to shoot ratio (0.30) and dry weight (5.66 g) of *Dalbergia latifolia* seedlings raised in potting medium containing neem cake (3.34 g) + soil + sand (2:1) at one fifty days of sowing. Uzokwe *et al.* (2011) assessed the response of *Albizia lebbeck* seedlings to liquid and solid cow dung manure application in the nursery. The results revealed that seedlings grown in Treatment 6 (Soil B + 0.2 litre of liquid manure had the highest value for plant height (29.8 cm), number of leaves (25.3), stem diameter (4 mm), number of branches (11) and leaf area (32.6 cm^2) respectively as compared to control. Kumar *et al.* (2018) observed the highest shoot length (23.82 cm), root length (21.14 cm), collar diameter (3.59 mm), shoot dry weight (1.94 g), root dry weight (1.04 g) and seedling quality index (0.35) in growing media comprising of soil + sand + vermicompost (1:1:1) for production of *Albizia lebbeck* seedlings. Handa *et al.* (2005) evaluated the response of different growing media on seedling growth and biomass of *Albizia amara*. The maximum shoot length (29 cm), root length (21.4 cm), number of leaves (17), dry weight of root (0.91 g), total biomass (2.17 g) and root to shoot ratio (0.74) were observed in sand + soil + FYM (1:2:1) media. Naugraiya and Tedia (2009) obtained maximum stem length (19.7 cm), number of leaves (16.3), root length (42.7 cm) and total dry weight (2.40 g/plant) in soil + FYM (1:3) for *Albizia amara* seedlings. Behera *et al.* (2024) determined the performance of different pre-sowing seed treatments, container size and potting mixture for quality seedlings of *Albizia procera*. The treatment combination $T_3C_1M_6$ *i.e.* pre-sowing treatment T_3 (seeds soaked in cow urine for 24 hours), polybag C_1 of size (23 cm x 13 cm), filled with growing medium sand + vermicompost (1:1) (M_6) noted best value for seedling height (21.8 cm), collar diameter (15.87 mm), vigour index (2521) and quality index (0.99). Olujobi *et al.* (2024) recorded the highest seedling height (17.02 cm), stem diameter (4.78 cm), and leaf number (5.82) of *Pterocarpus osun* seedlings raised in potting medium containing top soil amended with cow dung after 12 weeks of growth. Nzekwe *et al.* (2016) observed the highest seedling height (22.4 cm), number of leaves (24.5) and leaf area (196.3 cm^2) in growing media comprising of top forest soil + saw dust + poultry manure (2:1:1) for production of *Afzelia africana* seedlings.

Table 1: Influence of organic manures on quality seedling production of timber yielding nitrogen fixing tree species

Sr. no	Name of species	Organic manure treatment	Characters of quality seedling production	Source
1	*Dalbergia sissoo*	Karanj cake > groundnut cake > neem cake > linseed cake > mahua cake > mustard cake	enhanced shoot length, collar diameter, root length, number of leaflets, leaflet area, nodule number and biomass production	Mahto *et al.* (2007)
2	*Dalbergia latifolia*	Neem cake (3.34 g) + soil + sand (2:1)	highest seedling height, collar diameter, root length, number of root nodules and leaflets	Kumar *et al.* (2014)

			per plant, root to shoot ratio and dry weight	
3	*Albizia lebbeck*	Soil + sand + vermicompost (1:1:1)	exhibited maximum shoot length, root length, collar diameter, shoot dry weight, root dry weight and seedling quality index	Kumar *et al*. (2018)
4	*Albizia lebbeck*	Soil B + 0.2 litre of liquid manure	highest plant height, number of leaves, stem diameter, number of branches and leaf area	Uzokwe *et al.* (2011)
5	*Albizia amara*	Sand + soil + FYM (1:2:1)	exhibited maximum shoot length, root length, number of leaves, dry weight of root, total biomass and root to shoot ratio	Handa *et al*. (2005)
6	*Albizia amara*	Soil + FYM (1:3)	maximum stem length, number of leaves, root length and total dry weight	Naugraiya and Tedia (2009)
7	*Albizia procera*	$T_3C_1M_6$ *i.e.* pre-sowing treatment T_3 (seeds soaked in cow urine for 24 hours), polybag C_1 of size (23 cm x 13 cm), filled with growing medium sand + vermicompost (1:1) (M_6)	seedling height, collar diameter, vigour index and quality index	Behera *et al*. (2024)
8	*Pterocarpus osun*	Top soil amended with cow dung	highest seedling height, stem diameter, and leaf number	Olujobi *et al.* (2024)
9	*Afzelia africana*	Top forest soil + saw dust + poultry manure (2:1:1)	highest seedling height, number of leaves and leaf area	Nzekwe *et al.* (2016)

Organic manures in production of quality seedling of pulp yielding nitrogen fixing tree species

Production of quality planting material is significant for providing raw material for paper and pulp industries. The influence of organic manures in production of quality seedling of pulp yielding nitrogen fixing tree species is depicted in Table 2. Venkatesh *et al.* (2009) found that seedlings of *Casuarina equisetifolia* grown in the potting mixture comprising red soil + sand + goat manure (2:1:1) after three and five months of transplanting recorded maximum shoot length (56.10 and 71.40 cm respectively), root length (38.40 and 42.00 cm respectively), collar diameter (3.70 and 4.60 mm respectively), total dry weight (7.57 and 21.72 g respectively) and Dickson quality index (0.42 and 1.22 respectively) as compared to control. Rahi (2017) obtained maximum seedling height (69.51 cm), collar diameter (3.53 mm), seedling fresh weight (32.93 g) and seedling dry weight (10.21 g) in soil + sand (2:1) + 2.5 g nitrogen (N) applied through non-sterilized cake after eight months of growth for *Calophyllum inophyllum* seedlings. Nasir and Wani (2014) observed treatment T_1- soil: sand: FYM (1:1:1) showed highest in survival (70 %) and Dickson quality index (2.34) and also exhibited better results in root length, root to shoot ratio, total biomass, sturdiness quotient compared to other treatments on G48 clone of poplar. Guleria (2006) concluded that soil + sand (1:2) + FYM (@ 10 t/ha) resulted highest shoot length (24.04 cm), root length (31.08 cm), number of leaves (7.08), leaf area (84.11 cm^2), shoot weight (2.18 g) and seedling quality index (0.61) as compared to control for obtaining healthy and vigorous nursery stock of *Albizia chinensis*.

Table 2: Influence of organic manures on quality seedling production of pulp yielding nitrogen fixing tree species

Sr. no	Name of species	Organic manure treatment	Characters of quality seedling production	Source
1	*Casuarina equisetifolia*	Red soil + sand + goat manure (2:1:1)	maximum shoot length, root length, collar diameter, total dry weight and Dickson quality index	Venkatesh *et al.* (2009)
2	*Casuarina equisetifolia*	Soil + sand (2:1) + 2.5 g nitrogen applied through non-sterilized cake	maximum seedling height, collar diameter, seedling fresh weight and seedling dry weight	Rahi (2017)
3	G48 clone of poplar	Soil + sand + FYM (1:1:1)	exhibited maximum survival, Dickson quality index and exhibited better results in root length, root to shoot ratio, total biomass, sturdiness quotient	Nasir and Wani (2014)
4	*Albizia chinensis*	Soil + sand (1:2) + FYM (@ 10 t/ha)	highest shoot length, root length, number of leaves, leaf area, shoot weight and seedling quality index	Guleria (2006)

Organic manures in production of quality seedling of multipurpose nitrogen fixing tree species

Production of high-quality seedlings of multipurpose nitrogen fixing trees is vital for fulfilling the demand of food, fodder, fuelwood, firewood, charcoal, biodiesel, small timber, pulp, tan, dye, gum, resin, honey, medicine and other uses for sustaining the livelihood of rural communities. The influence of organic manures in production of quality seedling of multipurpose nitrogen fixing tree species is depicted in Table 3. Masilamani *et al.* (2002) obtained maximum germination (66.1 %), root length (29.0 cm), dry matter production (166 mg seedling^{-1}) and vigour index (3306) in control [red earth + sand + FYM (2:1:1)] after 28 days of growth. Further, the same treatment also noted highest shoot length (71.3 cm), root dry weight (4.65 g) and leaf area (31 cm^2) after 180 days of growth for *Pongamia pinnata* seedlings. Mansoori (2023) reported the best seedling growth of *P. pinnata* soil + sand + vermicompost (2:1:2) as evident from maximum plant height (75.49 cm), collar diameter (7.90 mm), number of leaves (36.37), diameter of tap root (5.80 mm), fresh weight of seedling (60.17 g), dry weight of seedling (27.95 g), root to shoot ratio (1.12), Dickson quality index (0.14), leaf chlorophyll content (3.31 mg/g) and survival (83.12 %). However, seedlings raised in control (soil only) remained inferior. The maximum BC ratio was found in (T_0) control (3.18) and the minimum (1.96) in soil + sand + vermicompost (T_{17}-1:2:1). Kumari (2024) recorded that the treatment comprising soil + sand + vermicompost (1:2:2) produced superior seedling vigour, as evident by maximum height (55.44 cm), taproot diameter (3.99 mm) at 50 % light intensity and biomass accumulation (total fresh weight: 7.54 g at 50 % light intensity, total dry weight: 3.96 g at open condition) and Dickson quality index (0.31) at open condition over other treatments for *Prosopis cineraria*. The media of soil + sand + vermicompost (1:1:2) excelled in collar diameter (4.11 mm at 25 % light intensity), root to shoot ratio (1.36 at open condition) and total chlorophyll content (1.31 mg/g tissue at 25 % light intensity) whereas the media of soil + sand + vermicompost (1:2:1) excelled in length of taproot (52.36 cm) in open condition. Overall, 50 % light intensity optimized seedling quality (shoot growth, taproot diameter, biomass), while open conditions maximized root development (length and root: shoot ratio). The maximum benefit to cost (BC) ratio of 1.83 was found in L_1P_0 (50 % light intensity in control media) treatment. Das (2024) recorded maximum value for growth parameters of *Myrica esculenta* such as shoot length (9.92 cm), collar diameter (1.77 mm), number of leaves (14.67), leaf area (9.70 cm^2), root length (20.38 cm), number of secondary roots (19.67) and root thickness (2.07 mm) in treatment combination C_3 (root trainer of 250 cc) × M_4 [soil + sand + vermicompost (1:1:1)] × T_5 (seeds treated with beejamrita solution for 3 weeks). Moreover, the same treatment also resulted maximum for seedling biomass and quality parameters such as total dry weight (1.57 g), percent fibrous roots (60.32 %), seedling vigour index (1344), Dickson quality index (0.40) and volume index (23.56). Rana *et al.* (2017) reported that seeds of *Parkia roxburghii* sown in potting mixture of soil, sand and FYM in ratio 1:2:4 (M_4) registered significantly maximum seedling growth parameters such as root length (16.57 cm), shoot length (18.02 cm), seedling height (34.59 cm) and collar diameter (4.70 mm). Moreover, the interaction effect of large size seeds (L_3) and the same potting mixture (M_4) resulted maximum root length (19.93 cm), shoot length (21.02 cm), seedling height (40.95 cm) and collar diameter (5.11 mm). Further, the interaction effect of soaking seeds for 24 hours in boiling water as pre-sowing seed treatment (T_5) with the same media (M_4) resulted maximum root length (19.58 cm), shoot length (21.79 cm), seedling height (41.37 cm) and collar diameter (5.03 mm). Chauhan (2024) concluded that raising *Acacia modesta* in (C_2) root trainers of 300 cc filled with (M_3) soil + sand + vermicompost (1:1:1) produced maximum seedling height (48.50 cm), collar diameter (3.99 mm), dry shoot weight (2.77 g), dry root weight (0.92 g), total seedling dry weight (3.70 g), seedling quality index (0.24) and the lowest sturdiness quotient (9.86) to obtain better quality seedlings. Yadessa *et al.* (2002) concluded that root collar diameter (4.30 mm), seedling height (33.06 cm), sturdiness quotient (7.69), shoot dry matter (2.02 g), root dry matter (0.54 g), root length (13.81 cm) and root to shoot ratio (0.33) were significantly higher in local soil + sand + FYM (3:1:2) for *Calliandra calothyrsus* seedlings. Raj *et al.* (2015) reported maximum plant height (55.70 cm), collar diameter (2.5 cm), number of leaves plant^{-1} (13.20), dry matter (10.27 g plant^{-1}), dry shoot weight (9.39 g plant^{-1}) and dry root weight (0.87 g plant^{-1}) in soil+ coir pith compost + vermicompost (2:1:1) for *C. calothyrsus* seedlings. Adedokun *et al.* (2019) recorded maximum shoot height (T_5: 40.05 cm), stem girth (T_1: 0.63 mm), number of leaves (T_2: 35.32) and number of leaflets (T_3: 289.50). Based on the results, T_5 (2 kg top soil + horse dung at 7.5 g) and T_1 (2 kg top soil + poultry manure at 5 g) were recommended for raising quality seedlings of *Tamarindus indica.* Mulugeta (2014) reported that the potting mixture containing forest soil + compost + sand (5:4:1) recorded maximum shoot length (42.73 cm), root length (18.10 cm), number of primary roots (31.67) and number of secondary roots (12.67) for *Albizia gummifera* seedlings. Further, the same treatment raised seedlings recorded maximum shoot dry matter (13.00 g), root dry matter (7.50 g), survival rate (95.00 %) and sapling height (120.42 cm), after one year of plantation in the field. Rahman *et al*. (2017) studied the influence of green manure potentials of water hyacinth and sewage sludge on seedling growth attributes of *Albizia saman.* The results revealed that sludge + hyacinth (1:1) resulted in highest collar diameter (7.87 mm), shoot length (116.67 cm), root length (54.00 cm), total seedling length (63.77 cm), number of nodes (57) and number of leaves (13). Further, the same treatment enhanced the fresh and dry weight of shoot (46.36 and 18.67 g respectively), total fresh and dry weight of root (22.60 and 9.80 g respectively) and total fresh and dry weight of seedling (68.66 and 28.47 g respectively) after four months indicating synergistic effects of sludge and hyacinth on the production of healthy seedlings. Iqbal *et al.* (2007) reported that an application of soil + residential sludge (1:1) recorded maximum shoot length (71.22 cm), root length (43.89 cm), total seedling length (115.11 cm), number of nodules (24), total fresh and dry weight of seedling (16.60 and 5.88 g respectively) and total dry biomass increment (608.43 %) as compared to control and higher vigour index (8978) of *Leucaena leucocephala* seedlings for better field establishment. Islam *et al.* (2019) recorded that *Acacia auriculiformis* seedlings raised in soil + cow dung (3:1) + phosphorus (0.16 g/polybag) resulted in highest shoot length (133.8 cm), nodule number (68), shoot fresh and dry weight (45.16 and 19.22 g respectively), biomass (23.86 g) and shoot to root ratio (4.05), whereas the highest root length (40.1 cm), collar diameter (7.9 cm), root fresh (9.16 g) and dry weight (4.72 g) and quality index (1.16) were recorded in the combination of soil + cow dung (3:1). Olaifa *et al.* (2021) reported that the best seedling growth of *Detarium microcarpum* was observed in treatment comprised of 40 g of *L. leucocephala* leaves + 2 kg top soil (T_1) as evident from maximum plant height (14.89 cm), collar diameter (5.23 mm), number of leaves (8.97), leaf area (214.89 cm^2), leaf dry weight (1.98 g), stem dry weight (0.95 g) and root dry weight (0.80 g) as compared to control. Emilda *et al.* (2021) evaluated the response of different growing media on seedling growth of *Pithecellobium lobatum* after six months of growth. The maximum plant height (83.24 cm), number of branches (8.47), number of leaves (68.08), total fresh weight (107.15 g), above ground dry weight (29.08 g), total dry weight (43.26 g) and number of root (6.91) were observed in soil: rice husk charcoal (1:1) media. Ginting *et al.* (2019) investigated the effect of biogas slurry *Sesbania grandiflora* seedlings for one month and they found that T_2- slurry dosage of 1000 ml slurry every 1 m^3 plant growing media showed highest plant height (5.35 cm), total leaf (9.03), number of branch (0.60) and stem diameter (1.72 mm) compared to other treatments.

Table 3: Influence of organic manures on quality seedling production of multipurpose nitrogen fixing tree species

Sr. no	Name of species	Organic manure treatment	Characters of quality seedling production	Source
1	*Pongamia pinnata*	Red earth + sand + FYM (2:1:1)	maximum germination, root length, dry matter production and vigour index after 28 days of growth. Highest shoot length, root dry weight and leaf area after 180 days of growth	Masilamani *et al.* (2002)
2	*Pongamia pinnata*	Soil + sand + vermicompost (2:1:2)	maximum plant height, collar diameter, number of leaves, diameter of tap root, fresh weight of seedling, dry weight of seedling, root to shoot ratio, Dickson quality index, leaf chlorophyll content and survival	Mansoori (2023)
3	*Prosopis cineraria*	(a) Soil + sand + vermicompost (1:2:2), (b) soil + sand + vermicompost (1:1:2), (c) soil + sand + vermicompost (1:2:1)	(a) enhanced height, taproot diameter, biomass accumulation, Dickson quality index, (b) collar diameter, root to shoot ratio, total chlorophyll content, (c) length of taproot	Kumari (2024)
4	*Myrica esculenta*	C_3 (root trainer of 250 cc) × M_4 [soil + sand + vermicompost (1:1:1)] × T_5 (seeds treated with beejamrita solution for 3 weeks)	maximum shoot length, collar diameter, number of leaves, leaf area, root length, number of secondary roots, root thickness, total dry weight, percent fibrous roots, seedling vigour index, Dickson quality index and volume index	Das (2024)
5	*Parkia roxburghii*	(a) Soil + sand + FYM (1:2:4) (M_4), (b) interaction effect of large size seeds (L_3) and the same potting mixture (M_4), (c) interaction effect of soaking seeds for 24 hours in boiling water as pre-sowing seed treatment (T_5) with the same media (M_4)	(a) maximum root length, shoot length, seedling height and collar diameter, (b) maximum root length, shoot length, seedling height and collar diameter, (c) maximum root length, shoot length, seedling height and collar diameter	Rana *et al.* (2017)
6	*Acacia modesta*	(C_2) root trainers of 300 cc filled with (M_3) soil + sand + vermicompost (1:1:1)	maximum seedling height, collar diameter, dry shoot weight, dry root weight, total seedling dry weight, seedling quality index	Chauhan (2024)

			and the lowest sturdiness quotient	
7	*Calliandra calothyrsus*	Local soil + sand + FYM (3:1:2)	highest root collar diameter, seedling height, sturdiness quotient, shoot dry matter, root dry matter, root length and root to shoot ratio	Yadessa *et al*. (2002)
8	*Calliandra calothyrsus*	Soil + coir pith compost + vermicompost (2:1:1)	maximum plant height, collar diameter, number of leaves plant^{-1}, dry matter, dry shoot weight and dry root weight	Raj *et al.* (2015)
9	*Tamarindus indica*	(a) T_5 (2 kg top soil + horse dung at 7.5 g), (b) T_1 (2 kg top soil + poultry manure at 5 g)	(a) maximum shoot height, (b) stem girth	Adedokun *et al*. (2019)
10	*Albizia gummifera*	Forest soil + compost + sand (5:4:1)	maximum shoot length, root length, number of primary roots and number of secondary roots after three months, maximum shoot dry matter, root dry matter, survival rate and sapling height after one year	Mulugeta (2014)
11	*Albizia saman*	Sludge + hyacinth (1:1)	highest collar diameter, shoot length, root length, total seedling length, number of nodes, number of leaves, fresh and dry weight of shoot, total fresh and dry weight of root and total fresh and dry weight of seedling	Rahman *et al*. (2017)
12	*Leucaena leucocephala*	Soil + residential sludge (1:1)	maximum shoot length, root length, total seedling length, number of nodules, total fresh and dry weight of seedling and total dry biomass increment and higher vigour index	Iqbal *et al.* (2007)
13	*Acacia auriculiformis*	Soil + cow dung (3:1) + phosphorus (0.16 g/polybag)	highest shoot length, nodule number, shoot fresh and dry weight, biomass and shoot to root ratio	Islam *et al*. (2019)
14	*Detarium microcarpum*	40 g of *Leucaena leucocephala* leaves + 2 kg top soil	maximum plant height, collar diameter, number of leaves, leaf area, leaf dry weight, stem dry weight and root dry weight	Olaifa *et al.* (2021)
15	*Pithecellobium lobatum*	Soil + rice husk charcoal (1:1)	maximum plant height, number of branches, number of leaves, total fresh weight, above ground dry weight, total dry weight and number of roots	Emilda *et al.* (2021)
16	*Sesbania grandiflora*	Slurry dosage of 1000 ml slurry every 1 m^3 plant growing media	highest plant height, total leaf, number of branch and stem diameter	Ginting *et al*. (2019)

Conclusion

Organic manures play a significant role in the sustainable production of high-quality seedlings of nitrogen-fixing tree (NFT) species by improving seedling growth, biomass accumulation, nodulation, survival, and overall seedling quality. Among the various organic amendments reviewed, vermicompost and FYM consistently exhibited superior performance due to their balanced nutrient supply, improved moisture retention, soil aeration, and beneficial microbial activity. Media combinations such as soil + sand + vermicompost (1:1:1) and soil + FYM-based mixtures produced vigorous seedlings in several NFT species including *Albizia lebbeck*, *Pongamia pinnata*, *Prosopis cineraria*, and *Casuarina equisetifolia*. For example, *P. pinnata* seedlings raised in soil + sand + vermicompost (2:1:2) recorded maximum plant height (75.49 cm) and survival (83.12 %), while *Leucaena leucocephala* seedlings grown in soil + residential sludge (1:1) showed 608.43 % increase in total dry biomass over control. Overall, incorporation of organic manures in nursery media offers an eco-friendly, cost-effective, and sustainable approach for producing vigorous and field-ready NFT seedlings for successful large scale afforestation programmes.

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