EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH OF *Santalum album* L. IN HORTI-SILVI SYSTEM

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INTRODUCTION

Santalum album is a highly valuable tree for its medicinal value and its demand in the highly preferred scented oil. Its cultivation is being expanded in the countries like Australia, Sri Lanka and Singapore on commercial scale in view of demand and supply gap. In India, the present production is less than 90 tonnes, of which more than 60 tonnes of oil required annually and more than 30 tonnes of sandalwood oil will be exported to other countries. Although demand for sandalwood and oil is increasing, supplies are declining (Ananthapadmanabha, 2000).

Santalum album L. is commonly known as Indian Sandalwood or 'Chandan'. The tree is a semi-root parasite of the family *Santalaceae*. Indian sandalwood is a threatened species which is indigenous to South India, and grows in the Western Ghats and a few other mountain ranges like the Kalrayan and Shevaroy hills, from Kerala in the South to Uttar Pradesh in the North. Most Sandal species have been exploited for their aromatic heartwood, which has customary, religious and medicinal significance in many eastern cultures (Srinivasan *et al*., 1992). In India, the genus is represented by *Santalum album* L. Sandalwood is found distributed all over the country (9600 km^2) with over 90 per cent of the area in Karnataka (5245 km^2) and Tamil Nadu (3040 km^2) rest in Andhra Pradesh (175 km^2), Orissa (35 km^2), Madhya Pradesh (33 km^2) and Maharashtra (84 km^2) (Nelson *et al.,* 2000).

S. album is an evergreen partial root parasite attaining 10-15 m height and 1-2 m girth at full maturity, when it reaches the age of 60-80 years (Ghosh *et al*., 1985). The tree flourishes well from sea level up to 1200 m altitude in regions with different soil types and varying climatic conditions and an annual precipitation of 600- 1600 mm. Bark is reddish brown to dark brown in colour, smooth in young trees, becoming rough with deep vertical fissures as the tree matures. Leaves are opposite, decussate, flowers unscented, straw-yellow coloured turning to deep purplish brown on maturation and occurs in axillary or terminal cymose panicles. Flowering generally occurs twice a year from March to May and September to December. The fruit is single- seeded succulent drupe, purplish black when mature (Srinivasan *et al.,* 1992).

In the context of fast depleting Sandalwood resources in the country, the major sandalwood growing states like Karnataka and Tamil Nadu governments liberalized the sandalwood trade partially during the year 2001 – 2002. This would facilitate the growers to grow more sandalwood in their *patta* lands. Now from the year 2001-2002 the Karnataka and Tamil Nadu have declared that the private land lords are the absolute owners of sandalwood grown in their *patta* lands. This would facilitate the land owners to cultivate the sandalwood in their lands for economic up-liftment. There is a need to remove the sandalwood from the state forest act in the context of sandalwood has been classified as medicinal plant by the "National Medicinal Plants Boards". Hence uniform act to be implemented to prioritize the cultivation of the depleting *Santalum album* at the national level.

The forests once protected due to inaccessibility have now been exposed to severe biotic factors including human interference leading to heavy exploitation and massive clearance, grazing, fire and the spike disease. Several causes have been attributed to the depletion of sandalwood population mainly amongst which theft is causing dysgenic effect on the quality of species by constant removal of superior trees. Therefore, assessment of genetic diversity is vital in developing effective conservation strategies and sustainable management guidelines (Radomiljac and Mc-comb, 1999). Producing commercially valuable sandalwood with high levels of fragrance oils requires being a minimum of eight years old trees, but at least fourteen year sandal trees are preferred.

Sandal cultivation has so far been restricted to government controlled lands, reserve forests and protected areas but liberalized policies suggested to grow *Santalum album* in the farmer's field. Hence information is lacking on growth, heart wood formation and compatibility with horticultural crops when grown on private lands under intensively managed conditions. The potential of the tree in existing farming or Silvi-horticultural systems with horticultural plants as secondary host for improving livelihood and creating employment opportunities and enhancing farm incomes is quite huge especially in semi-arid zones due to the less demanding climatic and edaphic requirements of this species.

Integrated Nutrient Management (INM) system aims at achieving efficient use of chemical fertilizers in conjunction with organic manures. Long term fertilizer experiments involving intensive cereal based cropping systems reveal a declining trend in productivity even with the application of recommended levels of N, P and K fertilizers (Mahajan and Sharma, 2005). It also maintains the soil fertility for sustaining increased crop productivity through optimizing all possible sources, organic and inorganic, of plant nutrients required for crop growth and quality in an integrated manner, appropriate to each cropping system and farming situation in its ecological, social and economic possibilities (Roy, 1986).

Integrated nutrient management intended for four major goals to be achieved. These are (1) To maintain soil productivity, (2) To ensure sustainable productivity, (3) To prevent degradation of the environment and (4) To reduce expenditure on the cost of chemical fertilizers (Agarwal, 1983).

The main concern of a farmer is to obtain sustainable high yields under local production conditions. The farmer can get profit from the adoption of modern planting principles, of which sustainability and INM play an important role. A balance sheet can be established for every nutrient. However, owing to the complexity involved, only the major nutrients N, P and K are generally considered. The efficiency of a production system depends on the importance of plant uptake versus the total supply of nutrients. High losses of nutrients limit the efficiency.

The present research is being taken in the plantation technology for *Santalum* since the research on these aspects is very megre. There is a vast scope in the agroforestry system to propagate *Santalum album* in the farmer's field. Keeping these points in view, the investigations on "effect of integrated nutrient management on growth of *Santalum album* in horti-silvi system" was undertaken with the following objectives.

1. To know the effect of integrated nutrient management on growth of *Santalum album*
2. To know the effect of integrated nutrient management on soil chemical properties

REVIEW OF LITERATURE

The relevant literature regarding the role of organic manures, inorganic fertilizers and bio-fertilizers on the growth attributes of forest trees in general and in particular and their effects on soil chemical properties of *Santalum album* are reviewed in this chapter.

2.1 Effect of organic manures on tree species

Organic manures constitute a dependable source of essential nutrients besides improving soil physical conditions. In most of the studies, organic manures have been primarily valued as important source of N, P and K and also serve as a potential source of micronutrients (Katyal, 1985).

Vigorous root growth, promoting development of haustoria and in turn increasing shoot growth, will be reflected in total dry weight, which may consequently be a good indicator of seedling quality, as concluded by Fox *et al.* (1990).

2.1.1 Effect of farm yard manure on plant growth and soil properties

Fernando (1966) reported that application of organic matter in the form of farm yard manure would improve the soil fertility. The humus formed by the decomposition of the plant debris was one of the most important constituents of soil, which forms the basis for maximum biological activity. Organic manure is an important plant nutrient and it regulates the soil physical properties.

Totey *et al*. (1986) reported that application of adequate quantity of farm yard manure maintains the soil fertility better than that of application of chemical fertilizers in teak seedlings.

Addition of FYM along with NPK fertilizer increased the available K status of the soil in teak (Arvind, 1987).

Santhy and Kothandaraman (1988) stated that combined application of FYM along with NPK resulted in higher organic carbon content than the control. Kumar *et al*. (1992) indicated that FYM did not affect bulk density of soil but increased the water stable aggregates (2 mm) in 3 and 4 years of *Acacia ariculiformis*.

Marigoudar (2001) reported that application of 2.5 kg of FYM + 30:15:30 g NPK per plant during first year of teak plantings recorded significantly higher height, collar diameter, number of leaves and crown spread compared to control and other levels of fertilizers.

Thirumurugan and Govindan (2001) studied combined application of organic manures, inorganic fertilizers and bio-fertilizers *viz.,* FYM (2.5 kg) + DAP (50 g) + Azospirillum (50 g) + phosphobacteria (50 g per tree). Higher plant height (437.9 cm) more girth (at bottom 50 and 100 cms) recorded at three and half year old neem.

Manjunath (2003) reported that application of 2.5 kg FYM with 30, 15 and 30 g N:P:K per teak plant recorded significantly higher height, collar diameter, number of leaves and crown spread compared to control.

Singh (2004) reported that among 4 treatments, FYM (2 kg/tree) treated plant, showed the maximum plant height (0.93 m). Plant height recorded in decreasing order is as follows: FYM (1.60 m) > fertilizer + FYM (1.46) > fertilizer (1.18 m) > control (1.21 m). Jitendra and Pawan (2006) studied the effect of organic and inorganic fertilizer treatments on growth, biomass and harvest index of *Prosopis cineraria* up to 24 months of growth periods under field condition and result showed that FYM treatment effectively contributed to the leaf yield, fresh branches and harvest index than control. Shukla and Kasera (2006) studied the nutritional treatments of organic and inorganic sources increased the growth parameters, bark and biomass yield of *Prosopis cineraria.*

2.1.2 Effect of vermicompost on tree growth

Norman and Edward (2005) reported that application of vermicompost can increase growth of trees. Similarly, vermicompost applied at very low rates *i.e.,* 2.5 t/ha or 5 t/ha can significantly increase growth of trees in the field.

Korwar *et al.* (2009) reported that maximum mean height and mean DBH showing highest in vermicompost + Inorganic fertilizers of 8.78 m & 7.52 cm respectively in *Leucaena leucocephala.*

Chandrakanth (2011) reported that vermicompost @ 2.5 tonnes per ha had significantly influenced the height, collar diameter, crown diameter and number of branches increment in *Eucalyptus pellita*.

Mohammad and Asgharipour (2012) reported that application of vermicompost 10 t/ha significantly increased the growth and yield of isabgol (*Plantago ovata*).

2.2 Effect of inorganic fertilizers on tree growth

Application of fertilizer has become very necessary to fulfil the objective of quick and better returns. Fertilizers are industrially manufactured chemicals containing plant nutrients. Nutrient content is higher in fertilizers than in organic manures and nutrients are released almost immediately. Plant nutrient requirement are met by soil contribution and fertilizer application.

Schutz (1976) reported that application of N, P_20_5, K_20 (2:2:2) to *Eucalyptus grandis* increased the volume by 40 per cent and height by 140 per cent more than control after four years. Schonau (1977) from six fertilizer experiments with *Eucalyptus grandis* found that initial improvement in height and diameter growth was usually high and significant.

Babaev (1978) reported that better height growth could be obtained with 120 kg/ha of N and 60 kg/ha of P_20_5 application to the plant of *Canadian poplars*. Growth of *Casuarina equisetifolia* and *Leuceana leucocephala* seedling was found maximum at 100 kg of Nitrogen per hectare and 300 kg P_2O_5 per hectare (Bumatay *et al*., 1988).

Rangaswamy *et al.* (1990) conducted an experiment on effect of inorganic fertilizers on seedlings of Casuarina, Sandal and Teak. Inorganic fertilizers in small doses on the seedlings of Casuarina and stumps of Teak boosted the growth of seedlings and stumps, whereas in Sandal it caused toxicity and subsequent mortality.

Dileep *et al.* (1991) reported that fertilizer has little effect on seedling height but it increased collar diameter in *Ceiba pentandra*. Soukhar and Kumbar (1991) reported that application of 200 kg, 100 kg P_2O_5 and 150 kg K_2O per ha to five month old teak seedlings exhibited significant growth.

Gupta (1991) reported that application of 50 g of super phosphate and 25 g of urea per plant increased the above and below ground biomass of *Pongamia pinnata*, *Albizia lebbeck*, *Leuceana leucocephala* and *Azadirechta indica* seedlings. Prasad and Rawat (1991) observed that height of *Acacia nilotica* significantly increased with increase in doses of nitrogen up to 100 ppm (63 cm). There was an increase of 61 per cent height in 100:100:50 N, P_2O5, K_2O kg/ha (195 cm) over control (121 cm).

Mutanal (1998) reported that during early stages of teak growth (12 and 16 months after planting), fertilizers level of 100, 50, 100 N, P_2O_5, K_2O kg/ha respectively would suffice for better growth further reported that main stem volume was significantly increased at 20 and 24 months after planting with the application of N, P_2O_5 and K_2O at the rate of 200: 100 and 200 kg/ha respectively.

Bhuiyan *et al.* (2000) recommended that the fertilizers of (0.6416 g of urea, 0.698 of TSP and 0.7615 g of MOP per seedling) for 5 months old *Casuarina equisetifolia* seedlings produced vigorous seedlings with high survival and maximum growth performance in comparison to control and other treatment combinations.

Venkatesh and Kumar (2001) opined that application of nitrogen at 15 g per plant and phosphorus 5 g per plant resulted in taller plants with better girth of silver oak (*Grevillea robusta*) at six months after planting under field conditions.

Mutanal *et al.* (2002) conducted field experiments in teak with three fertilizer levels, *viz*., D_1 (100 : 50 : 100), D_2 (200 : 100 : 200) and D_3 (300 : 150 : 300) N : P_2O_5 : K_2O kg/ha. The total biomass production at 28 months after planting increased significantly by 9.6 and 6.1 per cent in D_2 and D_3 levels respectively as compared to D_1 levels. Similar trend was observed in height, dbh and basal area.

Kumari *et al.* (2002) studied the establishment and growth of 6 months old clonal plants of *Eucalyptus tereticornis* in response to varying doses of N, P, K further reported that interaction of N, P and K at 60 kg of N, 90 kg of P_2O_5 and 60 kg of K_2O per ha was significant on height and basal girth than individual effects of N, P and K.

Lamani *et al.* (2003) reported that among various fertilizers tried, 200: 100: 200 Kg/ha of NPK was found to be most efficient in boosting various parameters such as height, collar diameter, crown diameter and volume of *Acacia auriculiformis*.

Lamani *et al.* (2001) reported that the maximum collar diameter of 1.90, 2.96, 4.22 and 5.05 cm at 1st, 2nd, 3rd and 4th interval respectively was recorded with application of 250:125:250 N, P_2O_5, K_2O kg/ha. The dosage of 250:125:250 N, P_2O_5, K_2O kg/ha resulted in the increased height of 1.49, 2.71,3.41 and 3.72m during 1st, 2nd, 3rd and 4th interval respectively as compared to other dosages in *Acacia auriculiformis*.

Fertilizer application has positive effect on growth of *Acacia mangium*. Application of 75:150:75 g/tree of N, P_2O_5, K_2O had recorded significantly higher stem volume compared to other fertilizers level (Patil *et al*., 2010).

Shivaputra (2011) reported that inorganic fertilizers had significant effect on growth parameters. 200:100:200 Kg/ha of N, P_2O_5, K_2O showed higher increment in plant height, collar diameter, crown diameter and number of branches increment in case of *Eucalyptus pellita*.

Sumathi *et al.* (2012) conducted the field experiment on effect of nitrogen and VAM levels on herbage and oil yield of patchouli (*Pogostemon patchouli*) under coconut shade. The study reveals that application of Nitrogen @ 150kg/ha and VAM at 50kg/ha enhanced the quantitative and qualitative traits and recorded maximum cost benefit ratio (1: 3.67).

2.3 Effect of bio-fertilizers on tree growth

Young (1990) reported that the mixed inoculum of *Phosphobacteria* and VAM promoted the seedling growth of *Acacia confusa, A. mangium* and *Leucaena formosana* but the inoculation of *Phosphobacteria* alone increased the available P content in the soil.

Girigis *et al.* (1991) reported that inoculation of *Frankia* promoted the growth and nodulation of *Casuarina glauca*. Parrotta (1991) showed that the duel inoculation of *Frankia* and *Rhizobium* at two months interval increased the growth of *Casuarina equisetifolia, Eucalyptus tereticornis, Leucaena leucocephala* and *Sesbania sesban*. Mansour *et al.* (1996) found that 20 months old seedlings of *Casuarina glauca* and *C. cunninghamiana* inoculated with *Frankia* displayed higher biomass, plant volume and nodule weight significantly over the control.

Subramanian *et al.* (1998) conducted a field experiment to investigate the effect of bio-fertilizers (*Azospirillum* and Phoshpobacterium) and mulch (coir pith) on the growth of young teak plantation. *Azospirillum* and Phosphobacterium along with mulch gave better results with respect to increase in height (20%) as well as girth (10.3%). There was no significant difference in growth when plants were inoculated separately with *Azospirillum* and Phosphobacterium.

Nelson *et al.* (2000) conducted an experiment on growth stimulation of *Santalum* seedlings by VAM fungi namely *Glomus fasciculatum* and *G. aggregatum* which improved the growth of the seedling by increased shoot and root length, stem thickness, and surface area of the leaves. Maximum growth promotion was recorded in *G. fasciculatum* treated plants in which the shoot length increased by 66.2%, fresh weight by 96.4%, and plant biomass by 94.7% over the control plant.

Mamatha *et al.* (2003) conducted an experiment on influence of the different VAM (*Glomus fasciculatum*) isolates on growth and nutrition of sandalwood plants. Inoculation of sandalwood plants with VAM fungi significantly improved plant growth and nutrition compared to the uninoculated plants.

Krishnan (2001) observed higher total dry weight of *Simarouba glauca* when the seedlings were inoculated with *Azotobactor* and *Phosphobacteria* @ 5 g per bag and VAM @10 g per bag. When *Azotobactor* and *Phosphobacteria* inoculated each @ 5 g per bag recorded the highest shoot length where as higher root length observed when inoculated with *Azotobactor* @ 5 g and VAM @ 10 g.

2.3.1 Effect of VAM on growth on tree species

Gurumurthy and Sreenivasa (1997) conducted an experiment to study the effect of inoculation of VAM (*Sclerocystis dussii*), P-solubilizer (*Pseudomonas striata*) in combination with SSP and rock phosphate on the growth of *Dalbergia sissoo* seedlings raised in 25×30 cm poly bags. Results after 6 months indicated that plant height, stem diameter, root length, leaf area, root and shoot dry weights were significantly higher in the inoculated seedlings (with SSP or RP) compared to individual inoculations without application of fertilizers.

Khan and Kamala (1999) reported that *Acacia nilotica* responded positively to VAM and *Rhizobium* inoculations with an increase of 40.9 per cent in biomass whereas in *Populus deltoids* an increase of 37.6 per cent was achieved with VAM inoculation in combination with normal dose of fertilizers.

Singh *et al.* (2000) reported that application of compost (2 kg) along with mixture of rhizobium and VAM (20 g) significantly increased the height, collar diameter and survival rate in 4.5 years old plants of *Albezia procera* and *Albezia lebbeck* respectively over control plants

Gurumurthy *et al.* (2001) conducted an experiment to study the effect of inoculation of VAM (*Sclerocystis dussii*), P-solubilizer (*Pseudomonas striata*) in combination with SSP and rock phosphate on the growth of one month old teak seedlings significantly increased the plant height, stem diameter, root length, leaf area, root and shoot dry weights in the inoculated seedlings (with SSP or RP) compared to individual inoculations.

Nagaveni *et al.* (2001) conducted an experiment on association of Sandal with VAM (*Glomus spp.*) fungi raised in polythene bag containing a potting mixture of sand, red earth, FYM (2:1:1) with the 100 g of VAM inoculation showed the increment in plant height, survival percentage and biomass in the nursery condition.

Mohan *et al.* (2001) reveals that the extent of root colonization and soil-spore population of VAM fungi from samples of both seedlings and adult trees in forest plantations of *Santalum album*.

2.4 Effect of combination of organic manures, inorganic fertilizers and bio-fertilizers on tree growth

Lal *et al.* (2005) reported that many intercropped plants were supplied micro and macro nutrients for increase of growth and fruit yield of mango. But the plant growth characters, fruit yield and quality parameters of mango not influenced due to presence of intercrop like pigeonpea, blackgram, sesame and toria.

Preetha *et al.* (2005) reported that five tonnes of vermicompost together with 50:50:50 kg/ha of N, P_2O_5, K_2O gave the highest vegetative yield as well as nutrient uptake, followed by 2.5 t/ha of Vermicompost +NPK, implying the synergistic effects of combined application of vermicompost and chemical fertilizers in *Amaranthus tricolor* L.

Kumar *et al.* (2009) reported that four organic sources (Farmyard manure, poultry manure, distillery bio-compost and city compost) were applied alone or super imposed over 25, 50 and 75% of recommended dose of inorganic fertilizers on N basis, and compared with control. Amongst the organic sources, the conjunctive use of 75% nutrients through fertilizers and 25% through FYM recorded maximum plant height, number of branches, number of compound leaves, fresh and dry herbage yield and total alkaloid yields (phyllanthin and hypo-phyllanthin), besides obtaining maximum net returns and highest benefit: cost ratio in *Phyllanthus amarus*.

Senthilkumar and Kanjana (2009) reveals that application of FYM @ 12.5 t/ha + *Azospirillum* + phosphobacteria recorded significantly maximum length of primary spike, more number of spikes per plant, capsules spike per plant, seed and oil yield and nutrient uptake as compared to pressmud @ 2 t/ha + *Azospirillum* + phosphobacteria and sugarcane bio-compost @ 1 t/ha in castor plants.

Paroha *et al.* (2009) studied the effect of inoculation of bio-fertilizers (AM, Azotobacter and PSB) and chemical fertilizers (NPK) on growth and nutrient acquisition of *Tectona grandis* and found that in all the combinations growth and nutrient uptake was significantly higher than uninoculated seedlings. AM and Azotobacter in combination was found to be most effective *i.e.* 3.91 times higher biomass than control.

Gupta *et al.* (2011) conducted a field experiment to study the effect of integrated nutrient management on herbage yield of black henbane (*Hyoscyamus niger*) and the result revealed that application of 75% recommended NPK along with 2.5 t vermicompost and bio-fertilizers increase the number of branches, number of leaves, stem yield, leaf yield *etc,.*

Brahmi *et al.* (2010) studied the effect of chemical and bio-fertilizers on production of quality seedlings of *Acacia catechu*. The chemical fertilizers used were Urea, SSP and MOP at three different levels and bio-fertilizers used were Rhizobium with VAM in combination which was applied @ 10 g/plant. Various morphological and quality parameters were recorded and the result recorded that N at 17.5 g/plant and P at 33 g/plant along with Rhizobium and VAM showed excellent morphological and quality features such as shoot length (27.60 cm), collar diameter (2.59 mm), root length (16.87 cm), Sturdiness quotient (107.9) and Dickson`s quality index (0.03) over control.

Revathi *et al*. (2012) studied the integrated nutrient management on the growth enhancement of *Dalbergia sissoo* seedlings. The result revealed that dual inoculation with bio-fertilizers (Rhizobium and AM) was impressive in improving the growth and biomass of Shisham under normal soil whereas in alkaline soil, blending of micronutrients with bio-fertilizers (Rhizobium + AM) had better growth and biomass.

2.5 Effect of integrated nutrient management on soil chemical properties

The combined application of coir-pith and inorganic amendments showed that coir-pith individually or with inorganic fertilizer improves the soil properties (Clarson *et al*., 1983). Ramasami and Sreeramalu (1983) reported that the application of raw coir pith along with NPK increased the yield of groundnut besides maintaining soil fertility.

Application of P either alone (Sharma and Meelu, 1975) or in combination with FYM (Prasad *et al*., 1971) continuously over a period enhanced the available N content due to the increase in the organic carbon content. In the red loam soils of the old and new permanent manorial experiments at Coimbatore, the available N content was found to be enhanced due to continuous incorporation of organic manures (Muthuvel *et al*., 1977).

Govindarajan and Rao (1978) reported that continuous addition of potassic fertilizers found to decrease the available N status of the soil. This could possibly due to the blocking up of absorbed NH_4 by added K preventing NH_4 from being released. Continuous addition of nitrogenous fertilizers leads to build up in the available N status of the soil (Chakraborthy, 1979).

Thiyagarajan *et al.* (1986) observed that application of P at 50 kg and 100 kg P_2O_5 per ha level with FYM increased the available N status of soil and among the sources of P fertilizers, super phosphate, DAP and RP were on par in increasing available N status of the soil compared to control.

Karikalan *et al.* (2005) conducted a field experiment to study the effect of graded levels of fertilizer nitrogen *viz.,* 0, 20, 40, 60, 80 and 100 kg N/ha on the dynamics of soil fertility and on the uptake of nutrients by the medicinal plants under Kapok (*Ceiba pentandra*) based agroforestry system. The uptake of N, P and K by the plants was higher in the open field than in the shaded field environment. Under the both field condition, the uptake of N, P and K by the medicinal plants increased progressively up to 100 kg N/ha.

Inorganic fertilization coupled with organics had a beneficial effect on soil available N content. When optimum amounts of NPK were combined with recommended levels of FYM, it was found to enhance the soil fertility in terms of available N and the same was documented by Subramanian and Kumaraswamy (1989) and Muthuswamy *et al.* (1990).

Kalia and Sharma (1985) stated that diffusion has to be considered as an important mechanism in P availability to plants. Sharpley (1985) observed that in both the unfertilized and fertilized soils, the pool of available P can be rapidly replenished from organic P and fertilizer P pool as a function of phosphatase enzyme activity and P sorption maximum, respectively. However, Brar *et al.* (1986) stated that high bonding energy of phosphate ions may be responsible for low P supply in the soil for plant growth.

Kanwar and Prihar (1962) in their studies on continuous application of FYM and inorganic fertilizers on properties of the soil observed that FYM with inorganic fertilizers increased the available K content of the soil. Nishita *et al.* (1973) reported that organic manure with inorganic fertilizers increased the available K content of the soil.

Singh and Mishra (1986) showed that all the sources of rock–phosphate behaved similarly and the availability of P increased as the proportion of pyrite in the mixture was increased.

Aravind (1987) observed that addition of FYM along with NPK fertilizer has increased the available K status of the soil. Kuo and Jellum (1987) showed that soil pH and soil N were responsible for variations of water soluble P in the soil. Santhy and Kothandaraman (1988) observed that the available P status of soil increased with P fertilization.

Chellamuthu (1990) stated that available K content of the soil was not significantly influenced either due to application of P and its sources. Santhy (1995) reported that continuous application of NPK fertilizer enhanced the available K status of the soil.

Singh *et al.* (1986) reported that continuous application of FYM to soil resulted in lowering the pH and increasing the organic carbon content. In general, application of FYM increased the organic carbon content in the soil (Kale and Sonar, 1984). Lavanya (1986) and Muthulakshmi (1988) reported that addition of coir-pith and NPK fertilizers increased the soil organic carbon. Sreekantan (1987) reported that the organic matter added through crop residues lead to the better growth and rooting of plants. Duraisamy *et al.* (1988) found that the application of organic manures improved organic carbon content in the soil.

Chellamuthu (1990) observed that organic carbon content of the soil was significantly influenced due to the application of P and its sources. Rajkumar *et al.* (1991) reported that an increase in the levels of various organic manures increased the organic carbon content in the soil. Santhy (1995) stated that combined application of 100% NPK along with FYM resulted in higher organic carbon than the control.

The combined application of mineral N with farm compost and recommended level of P and K based on soil fertility influenced the build-up of organic carbon and ammonical N (Saravanapandian, 1990).

2.6 Effect of bio-fertilizers on soil available nutrients

Rouatt and Katznelsan (1961) reported that *Phosphobacteria* when applied to rhizosphere soil having high organic matter content changed the insoluble form of phosphorus to soluble form. Phosphorus mobilizing bacteria (*Phosphobacter*) enhanced the availability of phosphorus in soil (Cooper, 1979).

The greater increase in seedling height and total dry weight of shola tree species correlated with improved accumulation of nitrogen due to *Azospirillum* (Wong and Stenberg, 1979) and phosphorus due to AM fungi and *Phosphobacteria* inoculation (Habte and Manjunath, 1987).

According to Beninwal *et al.* (1992) AM fungi could help in nodulation and nitrogen fixation in *Acacia nilotica* when inoculated with *Rhizobium*. Pokhriyal *et al.* (1992) reported that inoculation of soil with AM fungi and *Rhizobium* improved nitrogen fixation and nodulation in *Albizia lebbeck* and the same was documented by Sungavanum *et al.* (1998) in *Tectona grandis.*

MATERIAL AND METHODS

The present investigation entitled "effect of integrated nutrient management on growth of *Santalum album* L. in horti-silvi system" was carried out on farmer's field in Santholli village, near Dasanakoppa, (Uttar Kannada district) during 2012-13. Details about the experimental layout, materials used and methods employed during the course of investigation are presented in this chapter.

3.1 Experimental site

The present study was carried out in two and half year old existing *Santalum album* plantation in farmer's field of Santholli village, near Dasanakoppa, Uttara Kannada district. The experimental site is situated at 14^0 38' 57.5'' N latitude, 75^0 2' 22.6'' E longitudes and an altitude of 592 m above mean sea level (MSL).

The sandalwood seedlings were planted during 2010 in between two mango trees of one and half year old. The mango trees were planted with a spacing of 15m x 5m and sandalwood seedlings were planted with a spacing of 2.5m x 5m between the two mango trees. Later the farmer had applied FYM after one year of establishment. Farmer raised horse-gram as a sandal wood host plant and also vegetables as the intercrop. Irrigation is made through drip system and also it is found that drainage (half feet depth) was made in between the rows of sandal seedlings.

3.1.1 Climatic condition

The meteorological data recorded at ARS Malagi which is presented in Table 1 and depicted in Fig. 1, 2 and 3. The mean annual rainfall of 10 years at ARS Malagi was 1401.67 mm and highest rainfall was recorded in the month of July (364.68 mm) and minimum was recorded in the month of December (0.46 mm). During the study period (2012-13) total rainfall recorded was 922.20 mm which was less recorded (34.2 %) over mean of last 10 years (2002-11). The maximum rainfall recoded during experiment period was in the month of August (281.6 mm) and minimum rainfall was in the month of December (1.4 mm).

The average maximum temperature range was 26.6°C to 38.6°C. During experiment period, April was the hottest month and August lowest for maximum temperature, whereas minimum temperature range was 15.7°C to 22.8°C. During experiment period, January as lowest and May recorded highest minimum temperature.

3.2 Experimental details

The experiment consisted of two levels of organic manures, two levels of inorganic fertilizers and three levels of bio-fertilizers. The details are as follows:

Factor I: Organic manures

- O_1 – FYM (2 kg/ tree)
- O_2 –Vermicompost (1 kg/tree)

Factor II: Inorganic fertilizers

- I_1 – NPK_{100} [56:24:24 kg/ha (25:10:10g/tree)]
- I_2 – NPK_{150} [74:36:36 kg/ha (37.5:15:15g/tree)]

Factor III: Bio-fertilizer

- B_1 – VAM (100 g/tree)
- B_2 – PSB (100 g/tree)
- B_3 – Azospirillum (100 g/tree)

3.2.2 Design and layout

Design : Factorial Randomised Complete Block Design

Replication : 3 (Three)

Treatments : 12 (Twelve)

Number of trees/treatment: 5 (Five)

Plate 1. General view of the experimental site before imposition of treatments

Table 1. Meteorological data for the April 2012 to March 2013 and mean of last 10 years (2002-2011) at Agriculture Research Station, Malagi

Months	Rainfall (mm)		Temperature (ºC)			
			Maximum		Minimum	
	Mean (2002-11)	2012-13	Mean (2002-11)	2012-13	Mean (2002-11)	2012-13
April	61.93	84.8	35	33	20.7	22.7
May	56.97	9.6	33.3	31.8	22.1	23.2
June	262.06	127.2	28.8	28.6	21.2	22.8
July	364.68	208.7	26.6	25.5	20.9	22.5
August	340.24	281.6	26.8	25.4	20.7	22.5
September	149.47	105.8	28.3	25.8	20.7	22.1
October	98.99	15.3	29.9	27.2	20	20.7
November	49.52	64.8	30.1	29	17.4	18
December	0.46	1.4	29	28.9	14.5	16.4
January	0.98	10	31.3	29.9	14	15.7
February	3.85	4.8	33.5	31.4	14.4	17.5
March	12.52	8.2	38.6	32.8	17.8	20.9
Total	1401.67	922.2	371.2	349.3	224.4	245
Average	116.81	76.85	30.93	29.11	18.70	20.42

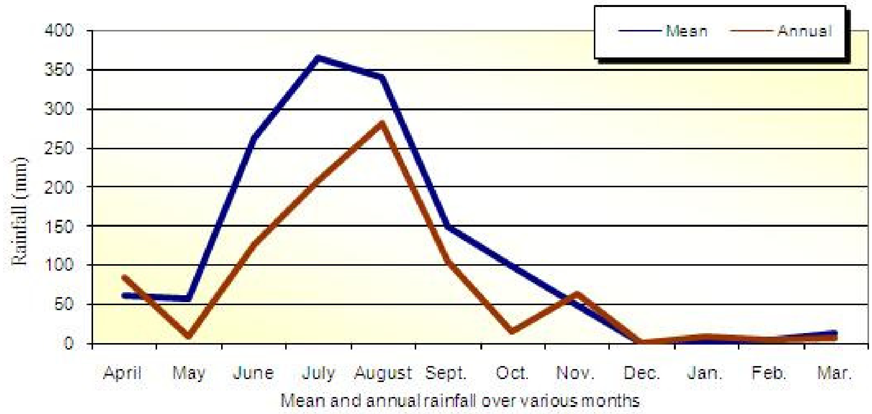


Fig. 1 Rainfall distribution for the period from April 2012 to March 2013 and mean of last 10 years (2002-2011)

Fig 1. Rainfall distribution for the period from April 2012 to March 2013 and mean of last 10 years (2002-2011)

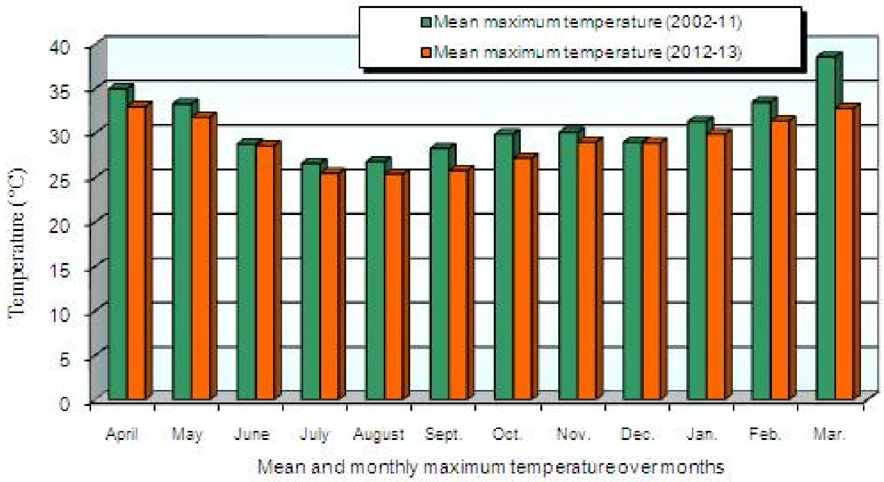


Fig. 2 Annual temperature (maximum) for the period from April 2012 to March 2013 and mean of last 10 years (2002-2011)

Fig 2. Annual temperature (maximum) for the period from April 2012 to March 2013 and mean of last 10 years (2002-2011)

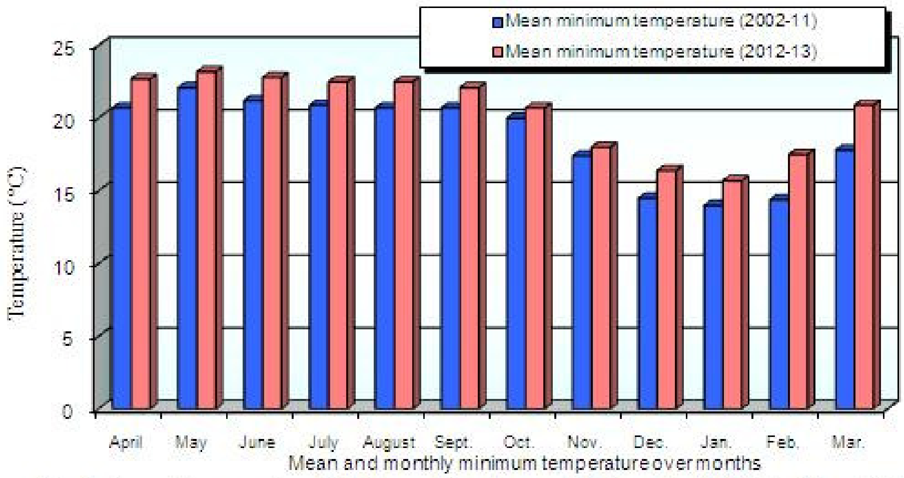


Fig. 3. Annual temperature (Minimum) for the period from April 2012 to March 2013 and mean of last 10 years (2002-2011)

Fig 3. Annual temperature (minimum) for the period from April 2012 to March 2013 and mean of last 10 years (2002-2011)

			T_1						T_4						T_6						T_2						T_{10}						T_{12}				
R_1	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m
		T_9						T_3						T_8						T_5						T_{11}						T_7					
	s	s	s	s	s	m	S	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	
			T_6						T_9						T_{12}						T_8						T_7						T_1				
R_2	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m
		T_3						T_5						T_4						T_{12}						T_2						T_{10}					
	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	
			T_5						T_7						T_9						T_6						T_1						T_8				
R_3	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m
		T_4						T_{12}						T_3						T_{10}						T_{12}						T_{11}					
	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	s	s	s	s	s	m	

Fig. 4. Field layout of the experiment (Factorial Randomized complete block design) with 12 Treatments and 3 Replication

*s= Sandal tree

*m=Mango tree

Combination of Treatments:

T_1 - O_1 + I_1 + B_1: (FYM + NPK $_{25:10:10\ g/tree}$ + VAM)

T_2 - O_1 + I_1 + B_2: (FYM + NPK $_{25:10:10\ g/tree}$ + PSB)

T_3 - O_1 + I_1 + B_3: (FYM + NPK $_{25:10:10\ g/tree}$ + Azospirillum)

T_4- O_2 + I_1+ B_1: (Vermicompost + NPK $_{25:10:10\ g/tree}$ + VAM)

T_5- O_2 + I_1 + B_2: (Vermicompost + NPK $_{25:10:10\ g/tree}$ + PSB)

T_6 - O_2 + I_1 + B_3: (Vermicompost + NPK $_{25:10:10\ g/tree}$ + Azospirillum)

T_7 - O_1 + I_2+ B_1: (FYM + NPK $_{37.5:15:15\ g/tree}$ + VAM)

T_8 - O_1 + I_2+ B_2: (FYM + NPK $_{37.5:15:15\ g/tree}$ + PSB)

T_9 - O_1 + I_2 + B_3: (FYM + NPK $_{37.5:15:15\ g/tree}$ + Azospirillum)

T_{10} - O_2 +I_2+ B_1: (Vermicompost + NPK $_{37.5:15:15\ g/tree}$ + VAM)

T_{11}- O_2+ I_2 + B_2: (Vermicompost + NPK $_{37.5:15:15\ g/tree}$ + PSB)

T_{12}- O_2 + I_2 + B_3: (Vermicompost + NPK $_{37.5:15:15\ g/tree}$ + Azospirillum)

The treatments were imposed during the month of July, 2012. The details of application are as follows.

3.2.3 Organic fertilizers application

The organic fertilizers (Farm yard manure and vermicompost) were powdered thoroughly and applied around the plants as per the treatments.

3.2.4 Bio-fertilizers application

The bio-fertilizers like VAM, PSB and *Azospirillum* culture was inoculated into the top soil as per the treatments.

3.2.5 Inorganic fertilizers application

The nutrient Nitrogen, Phosphorus and Potassium was supplied in the form of Urea, Rock phosphate and Mutate potash, respectively by ring method of application.

3.3 Collection of experimental data

Experimental data on growth parameters were recorded at one month interval up to eight month.

In each treatment trees were marked for recording and various growth parameters *viz.,* plant height, collar diameter, crown diameter, number of branches and average were worked out. These observations were recorded at monthly interval.

3.3.1 Plant height (m)

Plant height was measured from the base of the plant to tip of the main stem by using tape and expressed in meter.

3.3.2 Collar diameter (cm)

The diameter of the plant stem at collar region was recorded with the help of digital caliper and expressed in cm.

3.3.3 Crown diameter (m)

Crown spread was measured in two directions by holding the tape co-inciding the last tip of the branches. Average of the two readings were taken as crown diameter and expressed in meter.

3.3.4 Basal area (cm^2)

The cross sectional area at breast height was calculated by using formula given below and expressed in cm^2.

Plate 2. Imposition of treatments

$$\text{Basal area} = \frac{\pi(CD)^2}{4}$$

Where, CD= Collar diameter (cm)

3.3.5 Number of branches

By marking, cumulative branches were counted in each plant.

3.3.6 Light interception measurement

The intercepted light was recorded in digital values by using lux meter.

3.4 Soil chemical properties

Soil samples were taken twice *i.e.,* first before application of treatments to know the soil nutrient status and second one at the end of experiment. Individual samples were collected from different treatments randomly and various properties were analysed and recorded (Black, 1965).

3.4.1 Soil reaction (pH)

The soil reaction (pH) was determined in soil water suspension in the ratio of 1: 2.5 by Potentiometric method (Jackson, 1967).

3.4.2 Electrical conductivity

Electrical conductivity was determined in soil-water suspension in the ratio of 1: 2.5 by using Conductometric method (Jackson, 1973) and expressed as dSm^{-1}.

3.4.3 Organic carbon

The organic carbon content of soil sample was determined by Wet Oxidation Method as described by Jackson (1967) and expressed in per cent.

3.4.4 Available Nitrogen

Available Nitrogen was determined by alkaline potassium permanganate method as described by Subbiah and Asija (1956).

3.4.5 Available Phosphorus

Available Phosphorus was determined by Brays method (Jackson, 1967).

3.4.6 Available Potassium

Available Potassium was determined with Neutral ammonium acetate method as described by Jackson (1967).

3.5 Statistical analysis of the data

The data was analysed statistically using MSTAT-C programme by adopting Factorial Randomized Complete Block Design. The level of significance used in ‘F’ and ‘t’ tests was P=0.05. Critical difference values were calculated wherever ‘F’ test was significant.

Table 2. Details of methodology adopted for initial chemical properties of soil in the experimental site

Sl. No.	Chemical properties	Initial Value	Method used / reference
1	Soil pH (1:2.5)	5.21	Potentiometric method (Jackson, 1967)
2	EC (1:2.5) dSm^{-1}.	0.03	Conductometric method (Jackson, 1973)
3	Organic Carbon (%)	1.11	Wet Oxidation Method (Jackson, 1967)
4	Available Nitrogen (kg/ha)	176 kg/ha	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
5	Available P_2O_5 (kg/ha)	23.5 kg/ha	Brays method (Jackson,1967)
6	Available K_2O (kg/ha)	136 kg/ha	Neutral Normal Ammonium Acetate method (Jackson,, 1967)

EXPERIMENTAL RESULTS

The results of the experiment carried out during 2012-13 to know the effect of integrated nutrient management on *Santalum album* in horti-silvi system are presented in this chapter.

4.1 Growth parameters of *Santalum album*

4.1.1 Plant height (m)

The effect of organic manures, inorganic fertilizers and bio-fertilizers on plant height at different intervals was found to be significant (Table 3 and Fig. 5).

Plant height increased significantly with application of organic manures at different intervals of growth except at initial stage. At one month after treatment imposition the plant height (2.35 m) was significantly higher in plants receiving vermicompost @ 1 kg per tree compared to FYM @ 2 kg per tree (2.04 m). While at 2^{nd} and subsequent months there was a corresponding increase in plant height. At final stage of growth *i.e.,* at eight months, Application of vermicompost @ 1 kg/tree (2.94 m) recorded highest plant height compared to farm yard manure @ 2 kg/tree (2.56 m)

Among the inorganic fertilizers, the plant height increased significantly at different intervals of the growth except at initial stage, of one and two months after treatments respectively. At three MAT, the plant height was 2.55 m at 37.5:15:15 of N, P_2O_5, and K_2O g/tree. Same trend was also recorded at four, five, six and seven MAT. At final stage of growth *i.e.,* at eight months after treatment, the plant height (2.80 m) was found to be significant in $NPK_{37.5:15:15g/tree}$ compared to $NPK_{25:10:10\ g/tree}$ *i.e.,* 2.69 m.

In case of bio-fertilizer application, the plant height increased significantly at four, five, six, seven and eight MAT respectively. At four MAT, the plant height was 2.56 m in VAM @ 100 g/tree. Same trend was recorded at five, six and seven MAT. At final stage of growth *i.e.,* at eight MAT, the highest plant height (2.81 m) was recorded at VAM @100 g/tree, followed by Azospirillum @ 100 g/tree *i.e.* 2.79 m. The least plant height was recorded at PSB @ 100 g/tree *i.e.,* 2.65 m.

The interaction combination *i.e.* organic manures and inorganic fertilizer levels, there was no significant difference at any stage of growth.

Due to organic manures and bio-fertilizer application, the plant height increased significantly at four, five, six, seven and eight MAT respectively (Table 3a and Fig. 5a). The significantly higher plant height (2.95 m) was found in Vermicompost X PSB treatment which is on far with the treatment Vermicompost X VAM *i.e.,* 2.94 m at eight months. The least plant height was found in FYM X PSB treatment *i.e.,* 2.34 m.

In inorganic and bio-fertilizer combination interaction, plant height was increased significantly at four, five, six, seven and eight MAT (Table 3b and Fig. 5b). Significantly higher plant height (2.90 m) was found in $NPK_{37.5:15:15\ g/tree}$ X VAM treatment followed by $NPK_{37.5:15:15\ g/tree}$ X Azospirillum (2.88 m). The least plant height (2.63 m) was found in $NPK_{37.5:15:15\ g/tree}$ X PSB at eight MAT. Interaction effect of organic, inorganic and bio-fertilizer application was found to be non-significant.

4.1.2 Collar diameter (cm)

The effect of organic, inorganic and bio-fertilizers on collar diameter at different intervals was found to be significant (Table 4 and Fig. 6).

Collar diameter increased significantly with application of organic manures at different intervals of growth. At one month after treatment imposition the collar diameter (5.70 cm) was significantly higher in plants receiving vermicompost @ 1 kg per tree compared to FYM @ 2 kg per tree *i.e.,* while at second and subsequent months same trend was observed with respect to collar diameter.

At final stage of growth application of vermicompost @ 1 kg/tree recorded highest collar diameter (5.99 cm) compared to farm yard manure @ 2 kg/tree (5.64 cm).

Among the inorganic fertilizers, the collar diameter increased significantly after three month after treatment. At three MAT, the collar diameter was 5.65 cm at 37.5:15:15 of N, P_2O_5, and K_2O g/tree. Same trend was also recorded at four, five, six, seven MAT. At final stage of growth *i.e.* at eight MAT, the collar diameter (5.88 cm) was found to be significant in 37.5:15:15 N, P_2O_5, K_2O g/tree compared to 25:10:10 N, P_2O_5, K_2O g/tree *i.e.,* 5.75 cm.

Plate 3. Tagged plant and measurement of plant height using tape

Table 3. Effect of organic manures, inorganic fertilizers and bio-fertilizers on plant height (m) at different months after treatment

TREATMENTS	INITIAL	1 MAT	2 MAT	3 MAT	4 MAT	5 MAT	6 MAT	7 MAT	8 MAT
ORGANIC MANURES									
FYM	1.90	2.04	2.17	2.25	2.30	2.37	2.42	2.48	2.56
VERMICOMPOST	2.16	2.35	2.48	2.67	2.72	2.78	2.81	2.87	2.94
S.Em±	0.09	0.07	0.07	0.06	0.02	0.02	0.03	0.03	0.02
CD at 5%	NS	0.21	0.22	0.16	0.07	0.06	0.08	0.08	0.07
INORGNIC FERTILIZER									
$NPK_{25:10:10}$	1.96	2.14	2.26	2.37	2.42	2.47	2.52	2.60	2.69
$NPK_{37.5:15:15}$	2.11	2.24	2.39	2.55	2.61	2.68	2.71	2.75	2.80
S.Em±	0.12	0.09	0.09	0.07	0.03	0.03	0.04	0.03	0.03
CD at 5%	NS	NS	NS	0.20	0.08	0.08	0.10	0.10	0.09
BIO-FERTILIZER									
VAM	2.01	2.26	2.39	2.52	2.56	2.62	2.63	2.74	2.81
PSB	1.93	2.09	2.21	2.36	2.43	2.51	2.54	2.58	2.65
AZOSPIRILLUM	2.15	2.23	2.39	2.51	2.55	2.60	2.67	2.70	2.79
S.Em±	0.09	0.07	0.07	0.06	0.02	0.02	0.03	0.03	0.02
CD at 5%	NS	NS	NS	NS	0.07	0.06	0.08	0.08	0.07
INTERACTIONS ORGANIC×INORGANIC									
S.Em±	0.16	0.12	0.13	0.10	0.04	0.04	0.05	0.05	0.04
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
ORGANIC×BIO-FERTILIZER									
S.Em±	0.13	0.10	0.11	0.08	0.03	0.03	0.04	0.04	0.03
CD at 5%	NS	NS	NS	NS	0.09	0.09	0.12	0.11	0.10
INORGANIC×BIO-FERTILIZER									
S.Em±	0.16	0.12	0.13	0.10	0.04	0.04	0.05	0.05	0.04
CD at 5%	NS	NS	NS	NS	0.11	0.11	0.15	0.14	0.12
ORGANIC×INORGANIC×BIO-FERTILIZER									
S.Em±	0.23	0.18	0.18	0.14	0.06	0.05	0.07	0.07	0.06
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

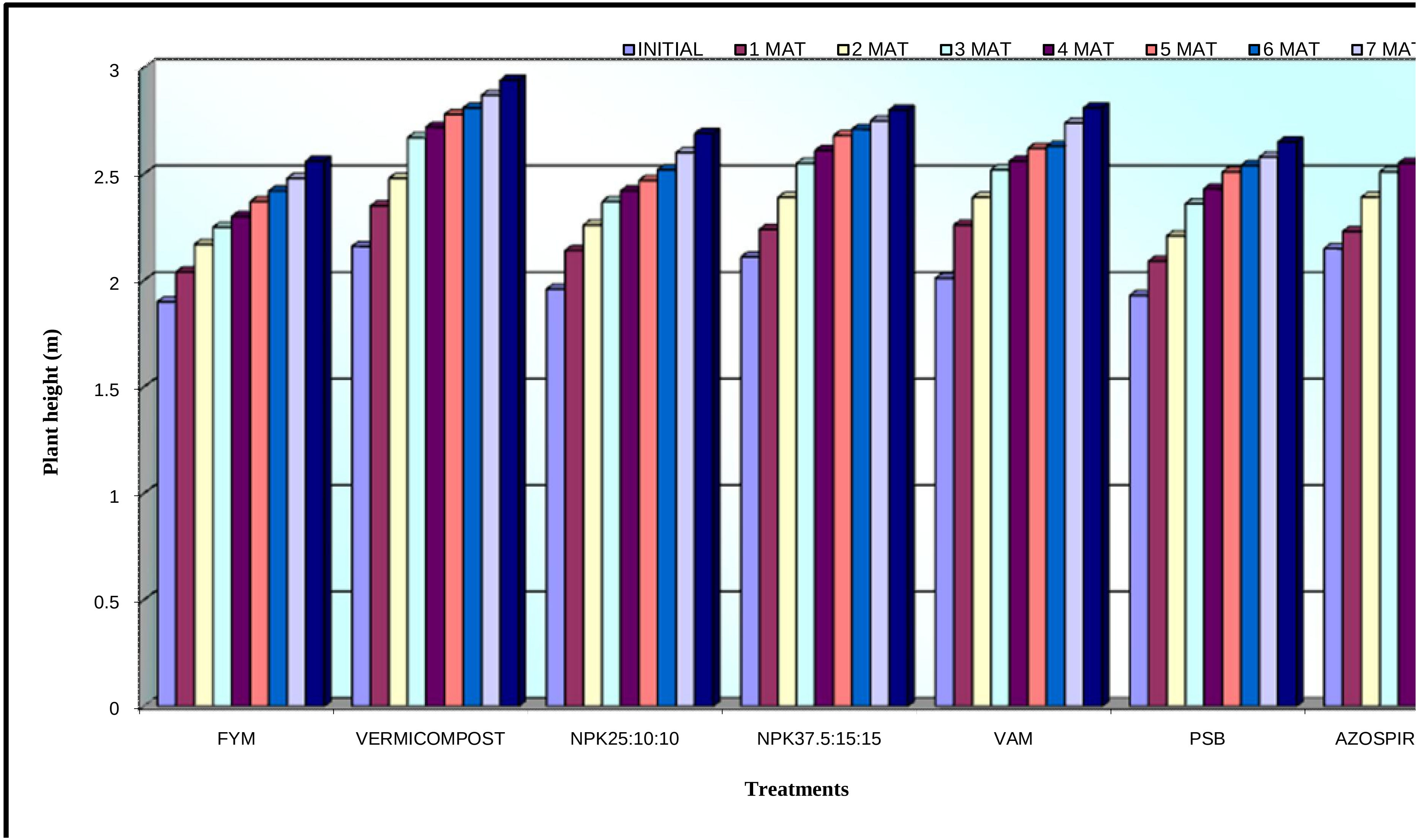

INITIAL
1 MAT
2 MAT
3 MAT
4 MAT
5 MAT
6 MAT
7 MA
3
2.5
2
1.5
1
0.5
0
Plant height (m)
FYM
VERMICOMPOST
NPK25:10:10
NPK37.5:15:15
VAM
PSB
AZOSPIR
Treatments

Table 3a. Interaction effect of organic fertilizer and bio-fertilizers on plant height (m) at different months after treatment

ORGANICS×BIO-FERTILIZERS									
Treatments	INITIAL	1 MAT	2 MAT	3 MAT	4 MAT	5 MAT	6 MAT	7 MAT	8 MAT
FYM X VAM	1.81	2.07	2.18	2.28	2.34	2.39	2.42	2.54	2.67
FYM X PSB	1.74	1.90	1.98	2.10	2.15	2.23	2.26	2.29	2.34
FYM X AZOS.	2.15	2.15	2.35	2.38	2.41	2.49	2.58	2.59	2.65
VERMI. X VAM	2.22	2.44	2.60	2.75	2.78	2.84	2.85	2.93	2.94
VERMI. X PSB	2.13	2.29	2.43	2.63	2.70	2.79	2.83	2.87	2.95
VERMI. X AZOS.	2.15	2.32	2.42	2.63	2.69	2.70	2.76	2.82	2.93
S.Em±	0.13	0.10	0.11	0.08	0.03	0.03	0.04	0.04	0.03
CD at 5%	NS	NS	NS	NS	0.09	0.09	0.12	0.11	0.10

Table 3b. Interaction effect of inorganic fertilizer and bio-fertilizers on plant height (m) at different months after treatment

INORGANICS×BIO-FERTILIZERS									
Treatments	INITIAL	1 MAT	2 MAT	3 MAT	4 MAT	5 MAT	6 MAT	7 MAT	8 MAT
$NPK_{25:10:10}$ X VAM	1.87	2.14	2.24	2.43	2.42	2.50	2.51	2.62	2.71
$NPK_{25:10:10}$ X PSB	2.00	2.06	2.24	2.32	2.40	2.48	2.53	2.59	2.67
$NPK_{25:10:10}$ X AZOS.	2.00	2.24	2.31	2.37	2.43	2.43	2.51	2.58	2.70
$NPK_{37.5:15:15}$ X VAM	2.16	2.37	2.53	2.60	2.70	2.74	2.76	2.85	2.90
$NPK_{37.5:15:15}$ X PSB	1.87	2.13	2.17	2.40	2.45	2.54	2.55	2.57	2.63
$NPK_{37.5:15:15}$ X AZOS.	2.29	2.23	2.47	2.64	2.68	2.76	2.83	2.82	2.88
S.Em±	0.16	0.12	0.13	0.10	0.04	0.04	0.05	0.05	0.04
CD at 5%	NS	NS	NS	NS	0.11	0.11	0.15	0.14	0.12

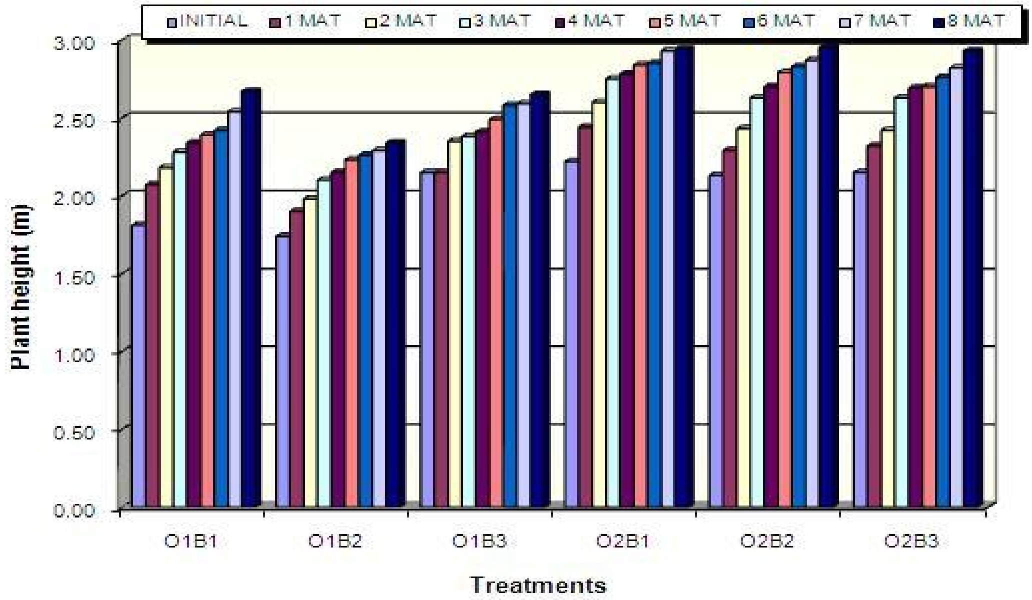


Fig. 5a. Interaction effect of organic fertilizer and bio-fertilizers on plant height (m) at different months after treatment

Legend: O_1- FYM; I_1- NPK $_{25:10:10\ g/tree}$; B_1- VAM; O_2- Vermicompost; I_2- NPK $_{37.5:15:15\ g/tree}$; B_2- PSB; B_3- Azospirillum; NS- Non Significant; MAT- Months after treatment

Fig 5a. Interaction effect of organic fertilizer and bio-fertilizers on plant height (m) at different months after treatment in *Santalum album*

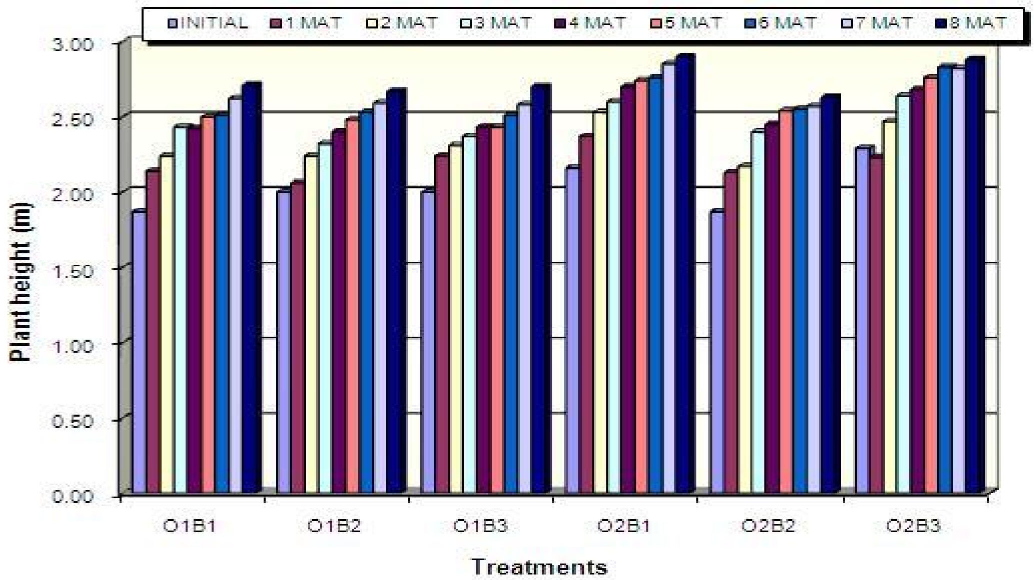


Fig. 5b. Interaction effect of inorganic fertilizer and bio-fertilizers on plant height (m) at different months after treatment

Legend: O_1- FYM; I_1- NPK $_{25:10:10\ g/tree}$; B_1- VAM; O_2- Vermicompost; I_2- NPK $_{37.5:15:15\ g/tree}$; B_2- PSB; B_3- Azospirillum; NS- Non Significant; MAT- Months after treatment

Fig 5b. Interaction effect of inorganic fertilizer and bio-fertilizers on plant height (m) at different months after treatment in *Santalum album*

Table 4. Effect of organic manures, inorganic fertilizers and bio-fertilizers on collar diameter (cm) at different months after treatment

TREATMENTS	INITIAL	1 MAT	2 MAT	3 MAT	4 MAT	5 MAT	6 MAT	7 MAT	8 MAT
ORGANIC FERTILIZER									
FYM	5.23	5.28	5.34	5.40	5.43	5.48	5.52	5.58	5.64
VERMICOMPOST	5.65	5.70	5.73	5.76	5.80	5.83	5.89	5.94	5.99
S.Em±	0.05	0.04	0.04	0.04	0.02	0.02	0.02	0.02	0.01
CDat5%	NS	0.13	0.11	0.11	0.06	0.06	0.05	0.05	0.04
INORGNIC FERTILIZER									
$NPK_{25:10:10}$	5.39	5.43	5.46	5.50	5.55	5.59	5.64	5.68	5.75
$NPK_{37.5:15:15}$	5.49	5.55	5.60	5.65	5.69	5.73	5.77	5.83	5.88
S.Em±	0.06	0.05	0.05	0.05	0.03	0.03	0.02	0.02	0.02
CDat5%	NS	NS	0.16	0.13	0.08	0.07	0.06	0.06	0.05
BIO-FERTILIZER									
VAM	5.46	5.53	5.58	5.63	5.67	5.71	5.75	5.82	5.86
PSB	5.39	5.43	5.47	5.52	5.57	5.60	5.66	5.71	5.76
AZOSPIRILLUM	5.48	5.51	5.54	5.58	5.61	5.67	5.71	5.75	5.82
S.Em±	0.05	0.04	0.04	0.04	0.02	0.02	0.02	0.02	0.01
CDat5%	NS	NS	NS	NS	NS	0.06	0.05	0.05	0.04
INTERACTIONS ORGANIC×INORGANIC									
S.Em±	0.09	0.08	0.07	0.07	0.04	0.04	0.03	0.03	0.02
CDat5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
ORGANIC×BIO-FERTILIZER									
S.Em±	0.07	0.06	0.06	0.05	0.03	0.03	0.02	0.03	0.02
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
INORGANIC×BIO-FERTILIZER									
S.Em±	0.09	0.08	0.07	0.07	0.04	0.04	0.03	0.03	0.02
CDat5%	NS	NS	NS	NS	NS	NS	0.08	0.09	0.07
ORGANIC×INORGANIC×BIO-FERTILIZER									
S.Em±	0.12	0.11	0.11	0.09	0.06	0.05	0.04	0.05	0.05
CDat5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

In case of bio-fertilizer application, the collar diameter increased significantly at five, six, seven and eight MAT respectively. At five MAT, the collar diameter was 5.71 cm in VAM @ 100 g/tree. Same trend was recorded at six, seven and eight MAT. At final stage of observation *i.e.,* eight MAT, the highest collar diameter (5.86 cm) was recorded in VAM @100 g/tree, followed by Azospirillum @ 100 g/tree *i.e.* 5.82 cm and the least collar diameter was recorded in PSB @ 100 g/tree *i.e.,* 5.76 cm.

In interaction combination *i.e.* organic manures and inorganic fertilizer application, organic manures and bio-fertilizer application, there was no significant difference at any stage of growth.

But in the combination of inorganic fertilizers and bio-fertilizer application, there was significant difference at six, seven and eight MAT respectively. The significantly higher collar diameter (5.97 cm) was found in $NPK_{37.5:15:15\ g/tree}$ X VAM treatment followed by $NPK_{37.5:15:15\ g/tree}$ X Azospirillum treatment (5.84 cm) and the least collar diameter (5.69 cm) was recorded in $NPK_{25:10:10\ g/tree}$ X PSB treatment at eight MAT (Table 4a and Fig. 6a).

Interaction effect of organic, inorganic and bio-fertilizer application was found to be non-significant.

4.1.3 Crown diameter (m)

The effect of organic, inorganic and bio-fertilizers on crown diameter at different intervals was found to be significant (Table 5 and Fig. 7).

Crown diameter increased significantly with application of organic manures at different intervals of growth except at initial stage. At one MAT, the crown diameter (1.49 m) was significantly higher in plants receiving vermicompost @ 1 kg per tree compared to FYM @ 2 kg/ tree. Same trend was observed up-to final stage of observation

At final stage of growth, application of vermicompost @ 1 kg/tree recorded highest crown diameter (1.93 m) compared to farm yard manure @ 2 kg/tree (1.77 m).

In the case of inorganic fertilizers application, the crown diameter increased significantly at different intervals of the growth except at initial stage, one MAT, two MAT and three MAT respectively. At four MAT, the crown diameter was 1.63 m at 37.5:15:15 of N, P_2O_5, K_2O g/tree. Same trend was also recorded at five, six, seven MAT. At final stage of growth *i.e.* eight MAT, the crown diameter increased significantly (1.90 m) at 37.5:15:15 N, P_2O_5, K_2O kg/ha followed by NPK $_{25:10:10g/tree}$ *i.e.,* 1.79 m treatment.

In the case of bio-fertilizers application, there was no significant difference at any stage of the growth.

In interaction combination *i.e.* organic manures and inorganic fertilizer levels, there was no significant difference at any stage of growth.

In organic manures and bio-fertilizer application, the crown diameter increased significantly at four, five, six, seven and eight MAT respectively. The significantly higher crown diameter (2.03 m) was recorded at Vermicompost X VAM treatment followed by Vermicompost X PSB treatment (1.89 m) and the least crown diameter was found in FYM X PSB (1.72 m) treatment (Table 5a and Fig. 7a).

In inorganic and bio-fertilizer combination interaction, there was no significant difference at any stage of growth.

In the combination interaction of organic, inorganic and bio-fertilizer application there was no significant difference at any stage of growth.

4.1.4 Basal area (cm^2)

The effect of organic, inorganic and bio-fertilizers on basal area at different intervals was found to be significant (Table 6 and Fig. 8).

Basal area increased significantly with application of organic manures at different intervals of growth. At one month after treatments imposition the basal area (25.50 cm^2) was significantly higher in plants receiving vermicompost @ 1 kg per tree followed by FYM @ 2 kg/tree. Same trend was observed up-to final stage of observation. At final stage of growth, application of vermicompost @ 1 kg/tree recorded highest basal area (28.16 cm^2) compared to farm yard manure @ 2 kg/tree (24.96 cm^2).

Table 4a. Interaction effect of inorganic fertilizer and bio-fertilizers on collar diameter (cm) at different months after treatment

INORGANICS×BIO-FERTILIZERS									
Treatments	INITIAL	1 MAT	2 MAT	3 MAT	4 MAT	5 MAT	6 MAT	7 MAT	8 MAT
$NPK_{25:10:10}$ X VAM	5.45	5.48	5.51	5.55	5.60	5.64	5.69	5.71	5.75
$NPK_{25:10:10}$ X PSB	5.30	5.34	5.37	5.44	5.49	5.49	5.56	5.61	5.69
$NPK_{25:10:10}$ X AZOS.	5.43	5.47	5.50	5.52	5.55	5.63	5.68	5.72	5.80
$NPK_{37.5:15:15}$ X VAM	5.48	5.58	5.66	5.72	5.74	5.77	5.82	5.92	5.97
$NPK_{37.5:15:15}$ X PSB	5.48	5.52	5.56	5.61	5.66	5.71	5.77	5.81	5.83
$NPK_{37.5:15:15}$ X AZOS.	5.53	5.56	5.58	5.64	5.67	5.70	5.74	5.77	5.84
S.Em±	0.09	0.08	0.07	0.07	0.04	0.04	0.03	0.03	0.02
CD a t5%	NS	NS	NS	NS	NS	NS	0.08	0.09	0.07

Legend: O_1- FYM; I_1- NPK $_{25:10:10\ g/tree}$; B_1- VAM; O_2- Vermicompost; I_2- NPK $_{37.5:15:15\ g/tree}$; B_2- PSB; B_3- Azospirillum; NS- Non Significant; MAT- Months after treatment

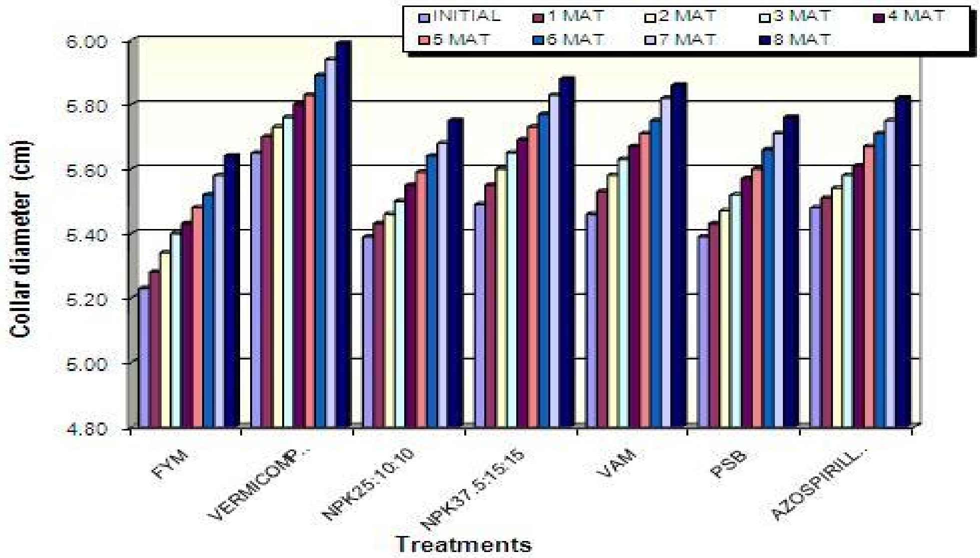


Fig. 6. Effect of organic, inorganic and bio-fertilizers on collar diameter (cm) at different months after treatment

Legend: O_1- FYM; I_1- NPK $_{25:10:10\ g/tree}$; B_1- VAM; O_2- Vermicompost; I_2- NPK $_{37.5:15:15\ g/tree}$; B_2- PSB; B_3- Azospirillum; NS- Non Significant; MAT- Months after treatment

Fig 6. Effect of organic manures, inorganic fertilizers and bio-fertilizers on collar diameter (cm) at different months after treatment in *Santalum album*

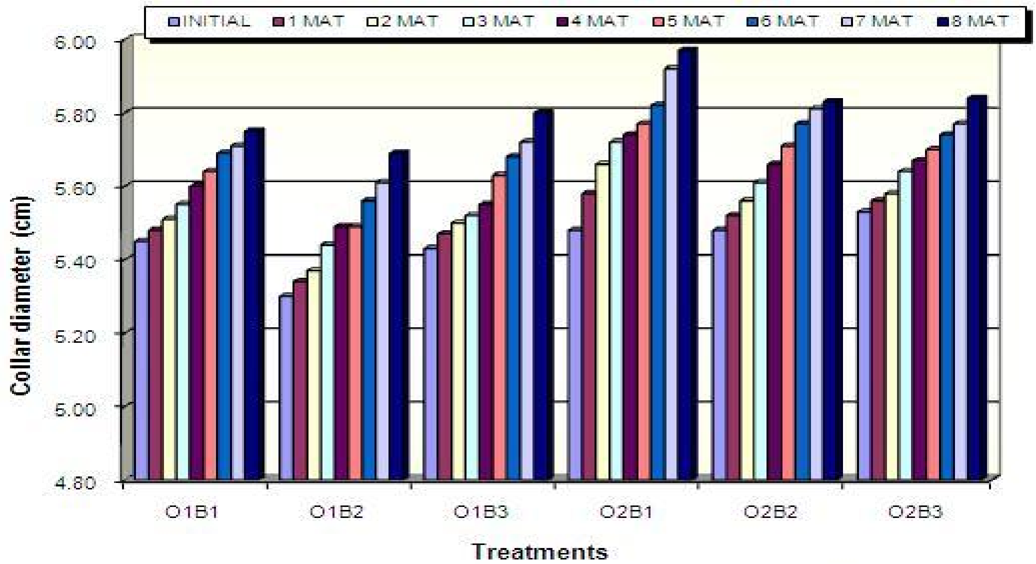


Fig. 6a. Interaction effect of inorganic fertilizer and bio-fertilizers on collar diameter (cm) at different months after treatment

Legend: O_1- FYM; I_1- NPK $_{25:10:10\ g/tree}$; B_1- VAM; O_2- Vermicompost; I_2- NPK $_{37.5:15:15\ g/tree}$; B_2- PSB; B_3- Azospirillum; NS- Non Significant; MAT- Months after treatment

Fig 6a. Interaction effect of inorganic fertilizer and bio-fertilizers on collar diameter (cm) at different months after treatment in *Santalum album*

Table 5. Effect of organic manures, inorganic fertilizers and bio-fertilizers on crown diameter (m) at different months after treatment

TREATMENTS	INITIAL	1 MAT	2 MAT	3 MAT	4 MAT	5 MAT	6 MAT	7 MAT	8 MAT
ORGANIC FERTILIZER									
FYM	1.35	1.38	1.42	1.47	1.52	1.57	1.64	1.71	1.77
VERMICOMPOST	1.43	1.49	1.55	1.60	1.64	1.71	1.78	1.86	1.93
S.Em±	0.04	0.05	0.04	0.04	0.03	0.03	0.03	0.03	0.03
CD at 5%	NS	0.16	0.13	0.12	0.09	0.10	0.09	0.08	0.08
INORGNIC FERTILIZER									
$NPK_{25:10:10}$	1.37	1.39	1.44	1.49	1.53	1.59	1.65	1.73	1.79
$NPK_{37.5:15:15}$	1.41	1.48	1.53	1.58	1.63	1.68	1.77	1.84	1.90
S.Em±	0.04	0.06	0.06	0.05	0.04	0.04	0.04	0.04	0.03
CD at 5%	NS	NS	NS	NS	0.11	0.11	0.11	0.10	0.10
BIO-FERTILIZER									
VAM	1.36	1.44	1.48	1.53	1.58	1.66	1.72	1.81	1.88
PSB	1.38	1.40	1.46	1.52	1.56	1.60	1.67	1.74	1.80
AZOSPIRILLUM	1.43	1.47	1.51	1.55	1.60	1.66	1.73	1.80	1.86
S.Em±	0.04	0.05	0.04	0.04	0.03	0.03	0.03	0.03	0.03
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
INTERACTIONS ORGANIC×INORGANIC									
S.Em±	0.06	0.09	0.08	0.07	0.05	0.05	0.05	0.05	0.05
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
ORGANIC×BIO-FERTILIZER									
S.Em±	0.05	0.07	0.06	0.06	0.04	0.04	0.04	0.04	0.04
CD at 5%	NS	NS	NS	NS	0.12	0.13	0.12	0.12	0.11
INORGANIC×BIO-FERTILIZER									
S.Em±	0.06	0.09	0.08	0.07	0.05	0.05	0.05	0.05	0.05
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
ORGANIC×INORGANIC×BIO-FERTILIZER									
S.Em±	0.09	0.13	0.11	0.10	0.07	0.08	0.07	0.07	0.07
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 5a. Interaction effect of organic fertilizer and bio-fertilizers on crown diameter (m) at different months after treatment

ORGANICS×BIO-FERTILIZERS									
Treatment	INITIAL	1 MAT	2 MAT	3 MAT	4 MAT	5 MAT	6 MAT	7 MAT	8 MAT
FYM X VAM	1.30	1.34	1.36	1.41	1.47	1.55	1.60	1.67	1.73
FYM X PSB	1.29	1.30	1.37	1.42	1.47	1.49	1.58	1.66	1.72
FYM X AZOS.	1.46	1.49	1.53	1.57	1.62	1.68	1.74	1.79	1.86
VERMI. X VAM	1.43	1.53	1.61	1.65	1.70	1.77	1.85	1.95	2.03
VERMI. X PSB	1.47	1.49	1.56	1.63	1.65	1.71	1.77	1.83	1.89
VERMI. X AZOS.	1.39	1.45	1.50	1.53	1.57	1.64	1.72	1.80	1.86
S.Em±	0.05	0.07	0.06	0.06	0.04	0.04	0.04	0.04	0.04
CD at 5%	NS	NS	NS	NS	0.12	0.13	0.12	0.12	0.11

Legend: O_1- FYM; I_1- NPK $_{25:10:10\ g/tree}$; B_1- VAM; O_2- Vermicompost; I_2- NPK $_{37.5:15:15\ g/tree}$; B_2- PSB; B_3- Azospirillum; NS- Non Significant; MAT- Months after treatment

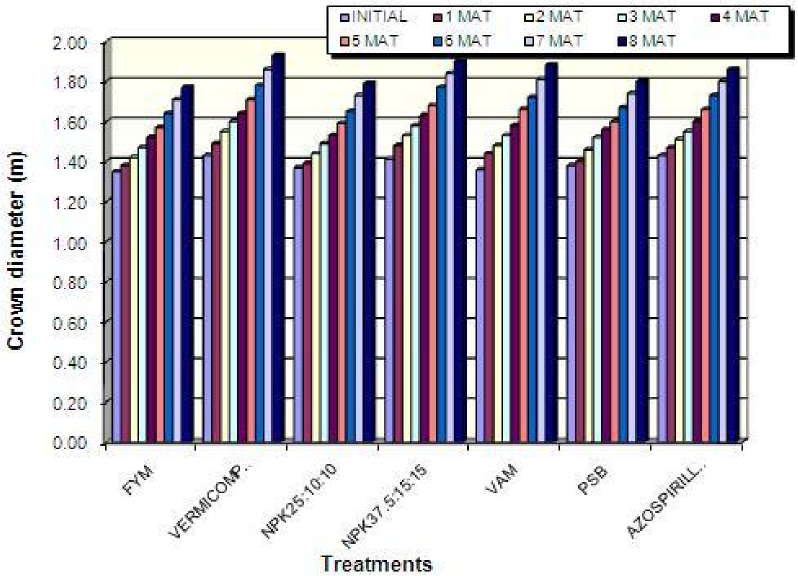


Fig. 7. Effect of organic, inorganic and bio-fertilizers on crown diameter (m) at different months after treatment

Legend: O_1- FYM; I_1- NPK $_{25:10:10\ g/tree}$; B_1- VAM; O_2- Vermicompost; I_2- NPK $_{37.5:15:15\ g/tree}$; B_2- PSB; B_3- Azospirillum; NS- Non Significant; MAT- Months after treatment

Fig 7. Effect of organic manures, inorganic fertilizers and bio-fertilizers on crown diameter (m) at different months after treatment in *Santalum album*

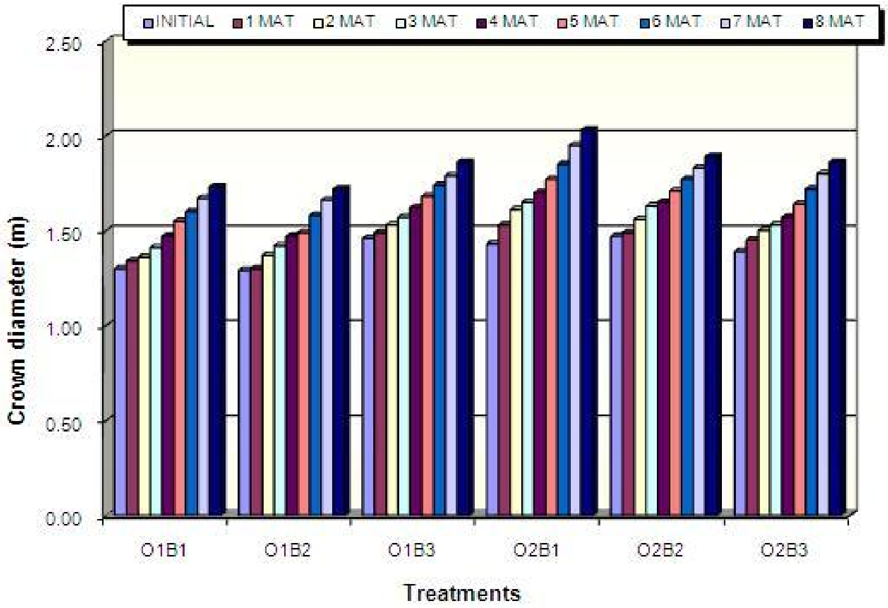


Fig. 7a. Interaction effect of organic fertilizer and bio-fertilizers on crown diameter (m) at different months after treatment

Legend: O_1- FYM; I_1- NPK $_{25:10:10\ g/tree}$; B_1- VAM; O_2- Vermicompost; I_2- NPK $_{37.5:15:15\ g/tree}$; B_2- PSB; B_3- Azospirillum; NS- Non Significant; MAT- Months after treatment

Fig 7a. Interaction effect of organic fertilizer and bio-fertilizers on crown diameter (m) at different months after treatment in *Santalum album*

Among the inorganic fertilizers, the basal area increased significantly at different intervals of the growth except at initial stage and one MAT respectively. At two MAT, the basal area was 24.65 cm^2 at 37.5:15:15 of N, P_2O_5, and K_2O g/tree. Same trend was also recorded at three, four, five, six, seven MAT. At final stage of growth *i.e.* at eight MAT, the basal area (27.17 cm^2) was found to be significant in 37.5:15:15 g/tree N, P_2O_5, K_2O, compared to 25:10:10 g/tree N, P_2O_5, K_2O *i.e.,* 25.96 cm^2.

In case of bio-fertilizer application, the basal area increased significantly at five, six, seven and eight MAT respectively. At five MAT, the basal area was 25.59 cm^2 in VAM @ 100 g/tree. Same trend was recorded at six, seven MAT. At final stage of growth *i.e.,* eight MAT, the highest basal area (26.98 cm^2) was recorded in VAM @100 g/tree, followed by Azospirillum @ 100 g/tree *i.e.* 26.62 cm^2 and the least basal area was recorded in PSB @ 100 g/tree *i.e.,* 26.08 cm^2.

In interaction combination *i.e.* organic manures and inorganic fertilizer application, organic manures and bio-fertilizer application, there was no significant difference at any stage of growth. But in the combination of inorganic fertilizers and bio-fertilizer application, there was significant difference at six, seven and eight MAT respectively. The significantly higher basal area (27.99 cm^2) was found in $NPK_{37.5:15:15\ g/tree}$ X VAM treatment followed by $NPK_{37.5:15:15\ g/tree}$ X Azospirillum treatment (26.79 cm^2) and the least basal area (25.44 cm^2) was recorded in $NPK_{25:10:10\ g/tree}$ X PSB treatment at eight MAT (Table 6a and Fig. 8a).

The interaction effect of organic, inorganic and bio-fertilizer application was found to be non-significant at all the observation intervals.

4.1.5 Number of branches

The effect of organic, inorganic and bio-fertilizers on number of branches at different intervals was found to be significant (Table 7 and Fig.9).

Number of branches increased significantly with application of organic manures at different intervals of growth except at initial and one MAT. At two month after treatments imposition the number of branches (16.89) was significantly higher in plants receiving vermicompost @ 1 kg per tree followed by FYM @ 2 kg/tree. Same trend was observed up-to final stage of observation. At final stage of growth, application of vermicompost @ 1 kg/tree recorded highest number of branches (39.62) compared to farm yard manure @ 2 kg/tree (34.35).

In the case of inorganic fertilizers application, the number of branches increased significantly at different intervals of the growth except at initial stage. At one MAT, the number of branches was 14.43 at 37.5:15:15 of N, P_2O_5, K_2O g/tree followed by $NPK_{25:10:10\ g/tree}$. Same trend was also recorded at two, three, four, five, six seven and eight MAT. At final stage of growth *i.e.* eight MAT, the significantly highest number of branches (38.00) were recorded at 37.5:15:15g/tree N, P_2O_5, K_2O followed by 25:10:10 g/tree N, P_2O_5, K_2O (35.97) treatment.

In case of bio-fertilizer application, the number of branches increased significantly at six, seven and eight MAT respectively. At six MAT, the number of branches were 26.86 in VAM @ 100 g/tree. Same trend was recorded at seven and eight MAT. At final stage of growth *i.e.,* eight MAT, the highest number of branches (37.96) was recorded in VAM @100 g/tree, followed by Azospirillum @ 100 g/tree *i.e.* 36.90 and the least number of branches was recorded in PSB @ 100 g/tree *i.e.,* 36.10.

In interaction combination *i.e.* organic manures and inorganic fertilizer application, organic manures and bio-fertilizer application, there was no significant difference at any stage of growth.

But in the combination of inorganic fertilizers and bio-fertilizer application, there was significant difference at six, seven and eight MAT respectively. The significantly higher number of branches (39.17) was found in $NPK_{37.5:15:15g/tree}$ X VAM treatment followed by $NPK_{37.5:15:15g/tree}$ X PSB treatment (37.80) and the least number of branches (34.40) was recorded in $NPK_{25:10:10\ g/tree}$ X PSB treatment at eight MAT (Table 7a and Fig. 9a).

The interaction effect of organic, inorganic and bio-fertilizer application was found to be non-significant at all the observations.

4.1.7 Light interception measurement

The data taken from one MAT to eight MAT at different time interval is given in Table 8 and Fig.10. At one MAT and two MAT, the data were collected by using lux meter at the scale of 10,000

Table 6. Effect of organic manures, inorganic fertilizers and bio-fertilizers on basal area (cm²) at different months after treatment

TREATMENTS	INITIAL	1 MAT	2 MAT	3 MAT	4 MAT	5 MAT	6 MAT	7 MAT	8 MAT
ORGANIC FERTILIZER									
FYM	21.54	21.95	22.39	22.88	23.16	23.59	23.97	24.42	24.96
VERMICOMPOST	25.07	25.50	25.75	26.07	26.45	26.70	27.25	27.70	28.16
S.Em±	0.43	0.38	0.38	0.34	0.21	0.19	0.14	0.17	0.12
CD at 5%	1.26	1.12	1.11	0.99	0.62	0.56	0.42	0.49	0.36
INORGNIC FERTILIZER									
$NPK_{25:10:10}$	22.87	23.21	23.49	23.83	24.18	24.52	25.02	25.38	25.96
$NPK_{37.5:15:15}$	23.74	24.24	24.65	25.12	25.43	25.77	26.19	26.74	27.17
S.Em±	0.53	0.47	0.46	0.41	0.26	0.23	0.17	0.21	0.15
CD at 5%	NS	NS	1.35	1.21	0.75	0.69	0.51	0.60	0.44
BIO-FERTILIZER									
VAM	23.47	24.06	24.52	24.93	25.25	25.59	25.99	26.59	26.98
PSB	22.85	23.20	23.54	24.01	24.43	24.63	25.21	25.63	26.08
AZOSPIRILLUM	23.60	23.91	24.14	24.49	24.74	25.23	25.62	25.96	26.62
S.Em±	0.43	0.38	0.38	0.34	0.21	0.19	0.14	0.17	0.12
CD at 5%	NS	NS	NS	NS	NS	0.56	0.42	0.49	0.36
INTERACTIONS ORGANIC×INORGANIC									
S.Em±	0.74	0.66	0.65	0.58	0.36	0.33	0.25	0.29	0.21
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
ORGANIC×BIO-FERTILIZER									
S.Em±	0.61	0.54	0.53	0.48	0.30	0.27	0.20	0.24	0.17
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
INORGANIC×BIO-FERTILIZER									
S.Em±	0.74	0.66	0.65	0.58	0.36	0.33	0.25	0.29	0.21
CD at 5%	NS	NS	NS	NS	NS	NS	0.72	0.86	0.63
ORGANIC×INORGANIC×BIO-FERTILIZER									
S.Em±	1.05	0.94	0.92	0.83	0.51	0.47	0.35	0.41	0.30
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 6a. Interaction effect of inorganic fertilizer and bio-fertilizers on basal area (cm^2) at different months after treatment

INORGANICS×BIO-FERTILIZERS									
Treatments	INITIAL	1 MAT	2 MAT	3 MAT	4 MAT	5 MAT	6 MAT	7 MAT	8 MAT
$NPK_{25:10:10}$ X VAM	23.34	23.61	23.91	24.18	24.63	24.99	25.41	25.62	25.98
$NPK_{25:10:10}$ X PSB	22.12	22.49	22.75	23.32	23.70	23.68	24.28	24.79	25.44
$NPK_{25:10:10}$ X AZOS.	23.16	23.52	23.81	23.99	24.23	24.90	25.38	25.72	26.45
$NPK_{37.5:15:15}$ X VAM	23.60	24.52	25.14	25.67	25.87	26.19	26.57	27.55	27.99
$NPK_{37.5:15:15}$ X PSB	23.58	23.91	24.33	24.70	25.16	25.57	26.15	26.47	26.72
$NPK_{37.5:15:15}$ X AZOS.	24.04	24.29	24.48	25.00	25.25	25.55	25.87	26.19	26.79
S.Em±	0.74	0.66	0.65	0.58	0.36	0.33	0.25	0.29	0.21
CD at 5%	NS	NS	NS	NS	NS	NS	0.72	0.86	0.63

Legend: O_1- FYM; I_1- NPK $_{25:10:10\ g/tree}$; B_1- VAM; O_2- Vermicompost; I_2- NPK $_{37.5:15:15\ g/tree}$; B_2- PSB; B_3- Azospirillum; NS- Non Significant; MAT- Months after treatment

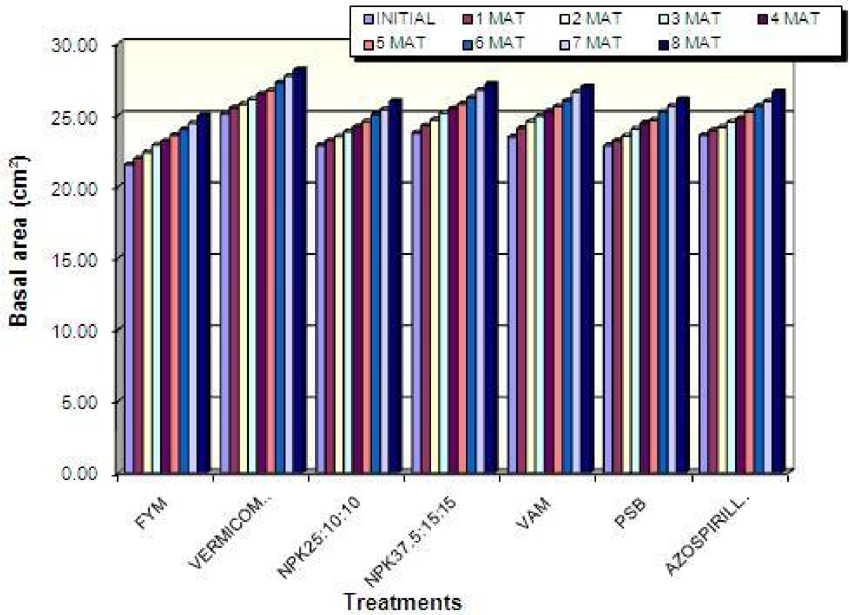


Fig. 8. Effect of organic, inorganic and bio-fertilizers on basal area (cm²) at different months after treatment

Legend: O_1- FYM; I_1- NPK $_{25:10:10\ g/tree}$; B_1- VAM; O_2- Vermicompost; I_2- NPK $_{37.5:15:15\ g/tree}$; B_2- PSB; B_3- Azospirillum; NS- Non Significant; MAT- Months after treatment

Fig 8. Effect of organic manures, inorganic fertilizers and bio-fertilizers on basal area (cm^2) at different months after treatments in *Santalum album*

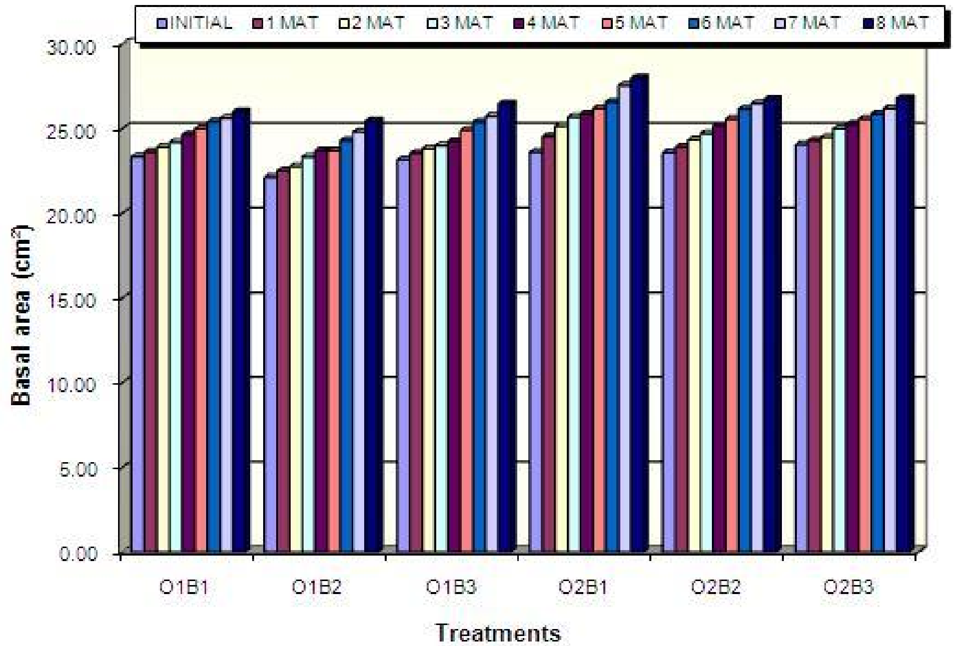


Fig. 8a. Interaction effect of inorganic fertilizer and bio-fertilizers on basal area (cm²) at different months after treatment

Legend: O_1- FYM; I_1- NPK $_{25:10:10\ g/tree}$; B_1- VAM; O_2- Vermicompost; I_2- NPK $_{37.5:15:15\ g/tree}$; B_2- PSB; B_3- Azospirillum; NS- Non Significant; MAT- Months after treatment

Fig 8a. Interaction effect of inorganic fertilizer and bio-fertilizers on basal area (cm^2) at different months after treatment in *Santalum album*

Table 7. Effect of organic manures, inorganic fertilizers and bio-fertilizers on number of branches at different months after treatment

TREATMENTS	INITIAL	1 MAT	2 MAT	3 MAT	4 MAT	5 MAT	6 MAT	7 MAT	8 MAT
ORGANIC MANURES									
FYM	12.95	13.74	15.01	17.29	19.40	23.21	26.24	29.85	34.35
VERMICOMPOST	13.08	14.06	16.89	19.08	21.98	25.97	28.46	33.22	39.62
S.Em±	0.36	0.35	0.28	0.36	0.32	0.43	0.38	0.31	0.34
CD at 5%	NS	NS	0.81	1.04	0.95	1.27	1.11	0.91	1.01
INORGNIC FERTILIZER									
$NPK_{25:10:10}$	12.71	13.37	15.34	17.51	19.80	23.76	26.74	30.67	35.97
$NPK_{37.5:15:15}$	13.32	14.43	16.56	18.86	21.58	25.41	27.95	32.40	38.00
S.Em±	0.44	0.43	0.34	0.44	0.40	0.53	0.46	0.38	0.42
CD at 5%	NS	1.26	0.99	1.28	1.16	1.55	1.35	1.12	1.24
BIO-FERTILIZER									
VAM	13.20	14.18	16.09	18.74	20.79	24.78	26.86	32.07	37.96
PSB	12.83	13.76	15.77	17.74	20.50	24.10	26.76	30.47	36.10
AZOSPIRILLUM	13.01	13.76	16.00	18.07	20.79	24.88	28.43	32.06	36.90
S.Em±	0.36	0.35	0.28	0.36	0.32	0.43	0.38	0.31	0.34
CD at 5%	NS	NS	NS	NS	NS	NS	1.11	0.91	1.01
INTERACTIONS ORGANIC×INORGANIC									
S.Em±	0.62	0.61	0.48	0.62	0.56	0.75	0.65	0.54	0.60
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
ORGANIC×BIO-FERTILIZER									
S.Em±	0.51	0.49	0.39	0.50	0.46	0.61	0.53	0.44	0.49
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
INORGANIC×BIO-FERTILIZER									
S.Em±	0.62	0.61	0.48	0.62	0.56	0.75	0.65	0.54	0.60
CD at 5%	NS	NS	NS	NS	NS	NS	1.91	1.58	1.75
ORGANIC×INORGANIC×BIO-FERTILIZER									
S.Em±	0.88	0.86	0.68	0.87	0.79	1.06	0.92	0.76	0.84
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 7a. Interaction effect of inorganic fertilizer and bio-fertilizers on number of branches at different months after treatment

INORGANICS×BIO-FERTILIZERS									
Treatments	INITIAL	1 MAT	2 MAT	3 MAT	4 MAT	5 MAT	6 MAT	7 MAT	8 MAT
$NPK_{25:10:10}$ X VAM	12.78	13.51	15.52	18.51	20.37	24.23	26.68	31.64	36.75
$NPK_{25:10:10}$ X PSB	12.49	13.23	15.10	16.73	19.25	22.72	25.17	28.62	34.40
$NPK_{25:10:10}$ X AZOS.	12.85	13.37	15.40	17.29	19.79	24.34	28.38	31.76	36.76
$NPK_{37.5:15:15}$ X VAM	13.63	14.84	16.66	18.97	21.20	25.32	27.03	32.50	39.17
$NPK_{37.5:15:15}$ X PSB	13.17	14.29	16.44	18.76	21.75	25.49	28.35	32.32	37.80
$NPK_{37.5:15:15}$ X AZOS.	13.17	14.16	16.59	18.84	21.79	25.42	28.48	32.37	37.04
S.Em±	0.62	0.61	0.48	0.62	0.56	0.75	0.65	0.54	0.60
CD at 5%	NS	NS	NS	NS	NS	NS	1.91	1.58	1.75

Legend: O_1- FYM; I_1- NPK $_{25:10:10\ g/tree}$; B_1- VAM; O_2- Vermicompost; I_2- NPK $_{37.5:15:15\ g/tree}$; B_2- PSB; B_3- Azospirillum; NS- Non Significant; MAT- Months after treatment

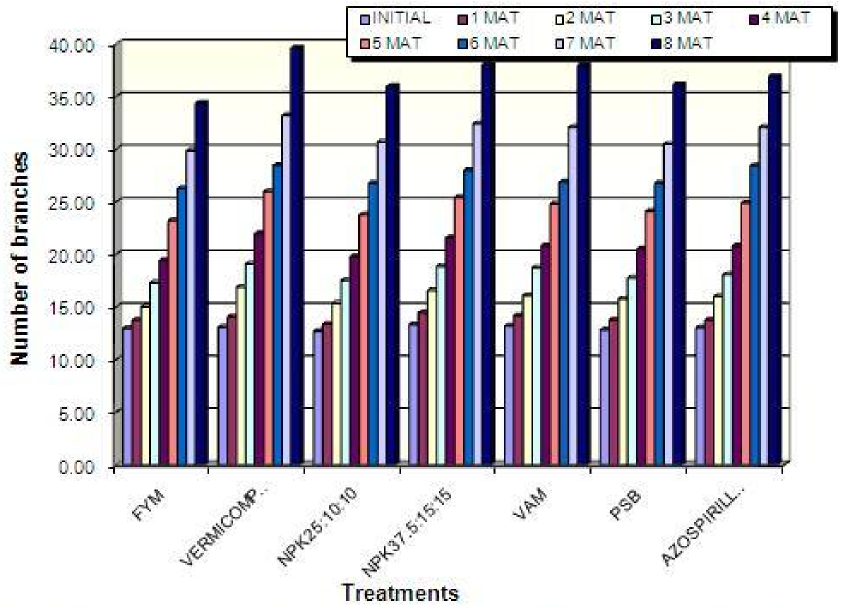


Fig. 9. Effect of organic, inorganic and bio-fertilizers on number of branches at different months after treatment

Legend: O_1- FYM; I_1- NPK $_{25:10:10\ g/tree}$; B_1- VAM; O_2- Vermicompost; I_2- NPK $_{37.5:15:15\ g/tree}$; B_2- PSB; B_3- Azospirillum; NS- Non Significant; MAT- Months after treatment

Plate 9. Effect of organic manures, inorganic fertilizers and bio-fertilizers on number of branches at different months after treatments in *Santalum album*

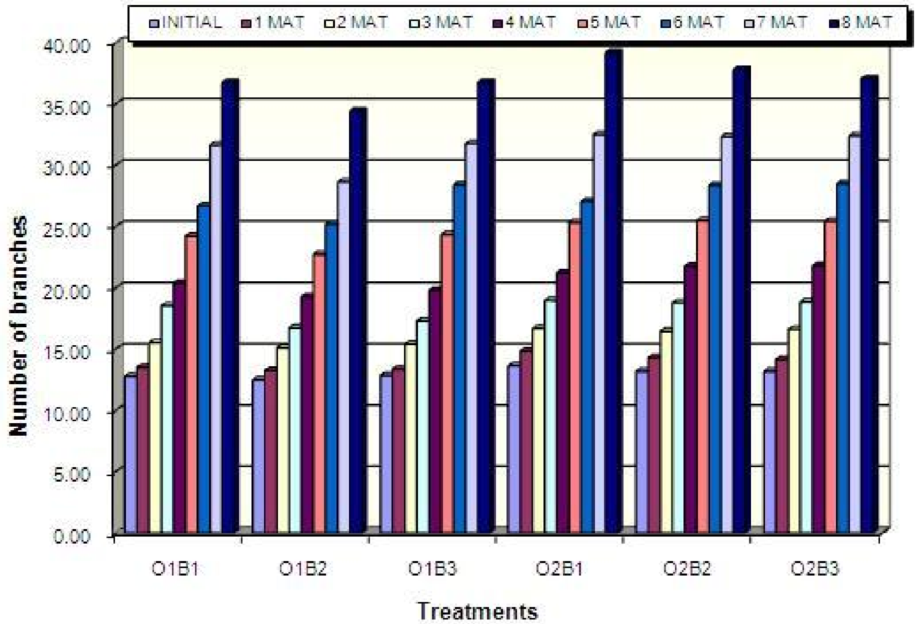


Fig. 9a. Interaction effect of inorganic fertilizer and bio-fertilizers on number of branches at different months after treatment

Legend: O_1- FYM; I_1- NPK $_{25:10:10\ g/tree}$; B_1- VAM; O_2- Vermicompost; I_2- NPK $_{37.5:15:15\ g/tree}$; B_2- PSB; B_3- Azospirillum; NS- Non Significant; MAT- Months after treatment

Plate 9a. Interaction effect of inorganic fertilizer and bio-fertilizers on number of branches at different months after treatment in *Santalum album*

lux due to the cloudy nature but after three MAT onwards due to clear weather condition and bright sun light the data were collected by 50, 000 scale in lux meter.

4.1.7.1 Effect of organic manures, inorganic manures and bio-fertilizers on light interception measurement in upper canopy

Organic manures did not influence significantly light interception in upper canopy. However maximum light intercepted in FYM treatment compared to vermicompost treatment (Table 8a and Fig. 10a).

Inorganic manures also did not influence significantly in upper canopy. However maximum light intercepted in $NPK_{25:10:10\ g/tree}$ treatment compared to $NPK_{37.5:15:15\ g/tree}$ treatment.

Among the bio-fertilizers also, the light interception did not show significant difference. However, the maximum light intercepted in PSB followed by VAM and least in Azospirillum treatment.

The interaction effect of organic, inorganic and bio-fertilizers was found to be non-significant at all the observation.

4.1.7.2 Effect of organic manures, inorganic manures and bio-fertilizers on light interception measurement in middle canopy

Organic manures did not influence significantly light interception in middle canopy. However maximum light intercepted in FYM treatment compared to vermicompost treatment (Table 8b and Fig. 10b).

Inorganic manures also did not influence significantly in middle canopy. However maximum light intercepted in $NPK_{25:10:10\ g/tree}$ treatment compared to $NPK_{37.5:15:15\ g/tree}$ treatment.

Among the bio-fertilizers also, the light interception did not show significant difference in middle canopy. However, the maximum light intercepted in PSB followed by VAM and least in Azospirillum treatment.

The interaction effect of organic, inorganic and bio-fertilizers was found to be non-significant with respect to middle canopy.

4.1.7.3 Effect of organic manures, inorganic manures and bio-fertilizers on light interception measurement in lower canopy

Organic manures did not influence significantly light interception in lower canopy. However maximum light intercepted in FYM treatment compared to vermicompost treatment (Table 8c and Fig. 10c).

Inorganic manures also did not influence significantly in lower canopy. However maximum light intercepted in $NPK_{25:10:10\ g/tree}$ treatment compared to $NPK_{37.5:15:15\ g/tree}$ treatment.

Among the bio-fertilizers also, the light interception did not show significant difference in lower canopy. However, the maximum light intercepted in PSB followed by VAM and least in Azospirillum treatment.

The interaction effect of organic, inorganic and bio-fertilizers was found to be non-significant with respect to lower canopy.

4.2 Chemical properties of soil

4.2.1 Soil pH

The data pertaining to effect of integrated nutrient management on soil pH after completion of the experiment (Eight MAT) is given in Table 9.

The application of organic manures did not have any significant effect on soil pH. However, the maximum pH was noticed in vermicompost (5.81) and minimum in FYM (5.78).

Among the fertilizer levels also, there was no significant variation in soil pH. However, the highest was noticed in $NPK_{25:10:10\ g/tree}$ (5.81) and the lowest were noticed in $NPK_{37.5:15:15\ g/tree}$ (5.78).

The application of bio-fertilizers did not have any significant effect on soil pH. However, the maximum pH was noticed in PSB (5.85) followed by VAM (5.79) and minimum in Azospirillum (5.75).

Table 8a. Effect of organic manures, inorganic fertilizers and bio-fertilizers on light interception (lux) on upper canopy in *Santalum album* at different months after treatment

TREATMENTS	1 MAT (11.30 am) *10000 lux	2 MAT (12 am) *10000 lux	3 MAT (11.30 am) * 50000 lux	4 MAT (11 am) * 50000 lux	5 MAT (9.30 am) * 50000 lux	6 MAT (11.00 am) * 50000 lux	7 MAT (10.15 am) * 50000 lux	8 MAT (11.40 am) * 50000 lux
ORGANIC MANURES								
FYM	49875185.19	68823703.7	48125462.96	35806928.89	35738215.56	35680210.39	35620426.39	35560642.39
VERMICOMPOST	8882037.037	76910185.19	8857037.037	8821685.037	8765210.037	8698026.87	8626792.87	8555558.87
S.Em±	4945528.787	2777196.949	4760936.379	4159057.399	4158846.853	4159243.385	4159624.503	4160005.808
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
INORGNIC FERTILIZER								
$NPK_{25:10:10}$	24113703.7	68206111.11	36363611.11	24045077.04	23980954.2	23916831.37	23852467.37	23788103.37
$NPK_{37.5:15:15}$	34643518.52	77527777.78	20618888.89	20583536.89	20522471.39	20461405.89	20394751.89	20328097.89
S.Em±	6057011.018	3401357.721	5830932.413	5093784.219	5093526.355	5094012.005	5094478.777	5094945.779
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
BIO-FERTILIZER								
VAM	26875555.56	61171666.67	45262916.67	26802791.56	26737140.06	26676074.56	26612855.56	26549636.56
PSB	51928055.56	78415277.78	30933055.56	30897703.56	30836638.06	30770986.56	30704332.56	30637678.56
AZOSPIRILLUM	9332222.222	79013888.89	9277777.778	9242425.778	9181360.278	9120294.778	9053640.778	8986986.778
S.Em±	4945528.787	2777196.949	4760936.379	4159057.399	4158846.853	4159243.385	4159624.503	4160005.808
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
INTERACTIONS ORGANIC×INORGANIC								
S.Em±	8565907.129	4810246.219	8246183.7	7203698.726	7203334.051	7204020.864	7204680.979	7205341.42
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
ORGANIC×BIO-FERTILIZER								
S.Em±	6994033.884	3927549.591	6732980.797	5881795.38	5881497.624	5882058.404	5882597.386	5883136.634
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
INORGANIC×BIO-FERTILIZER								
S.Em±	8565907.129	4810246.219	8246183.7	7203698.726	7203334.051	7204020.864	7204680.979	7205341.42
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
ORGANIC×INORGANIC×BIO-FERTILIZER								
S.Em±	12114022.04	6802715.441	11661864.83	10187568.44	10187052.71	10188024.01	10188957.55	10189891.56
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS

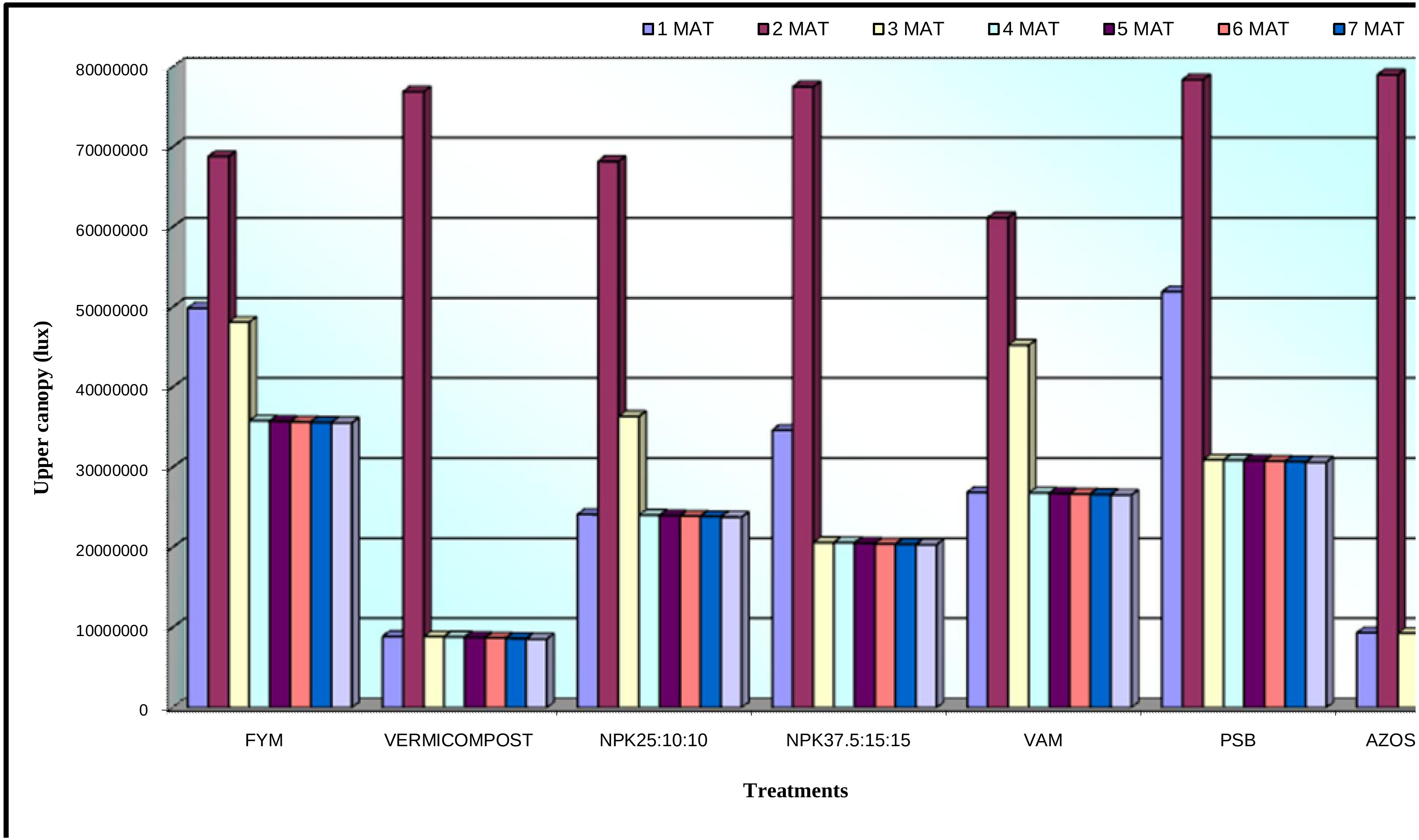
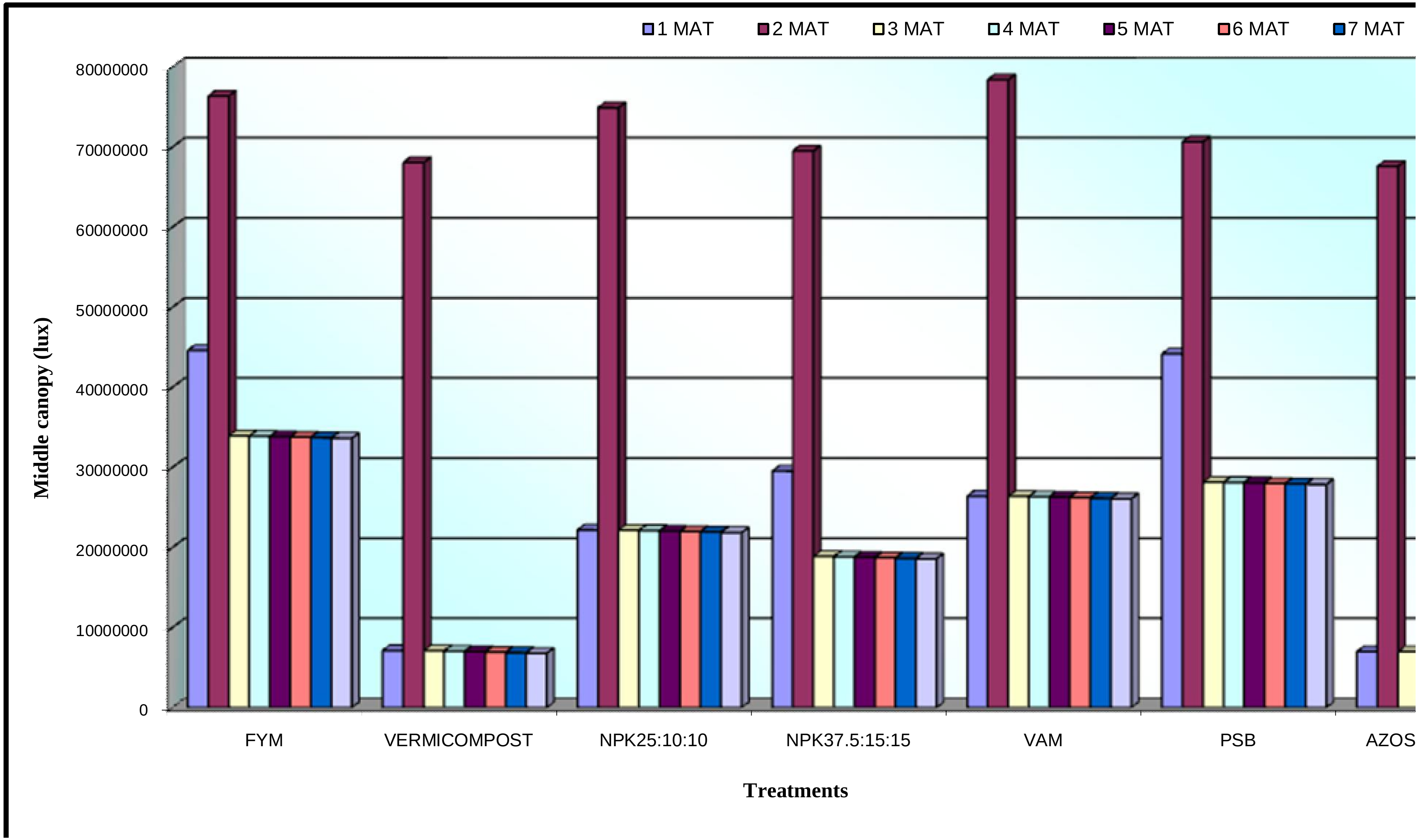

1 MAT
2 MAT
3 MAT
4 MAT
5 MAT
6 MAT
7 MAT
Upper canopy (lux)
80000000
70000000
60000000
50000000
40000000
30000000
20000000
10000000
0
FYM
VERMICOMPOST
NPK25:10:10
NPK37.5:15:15
VAM
PSB
AZOS
Treatments

Table 8b. Effect of organic manures, inorganic fertilizers and bio-fertilizers on light interception (lux) on Middle Canopy in *Santalum album* at different months after treatment

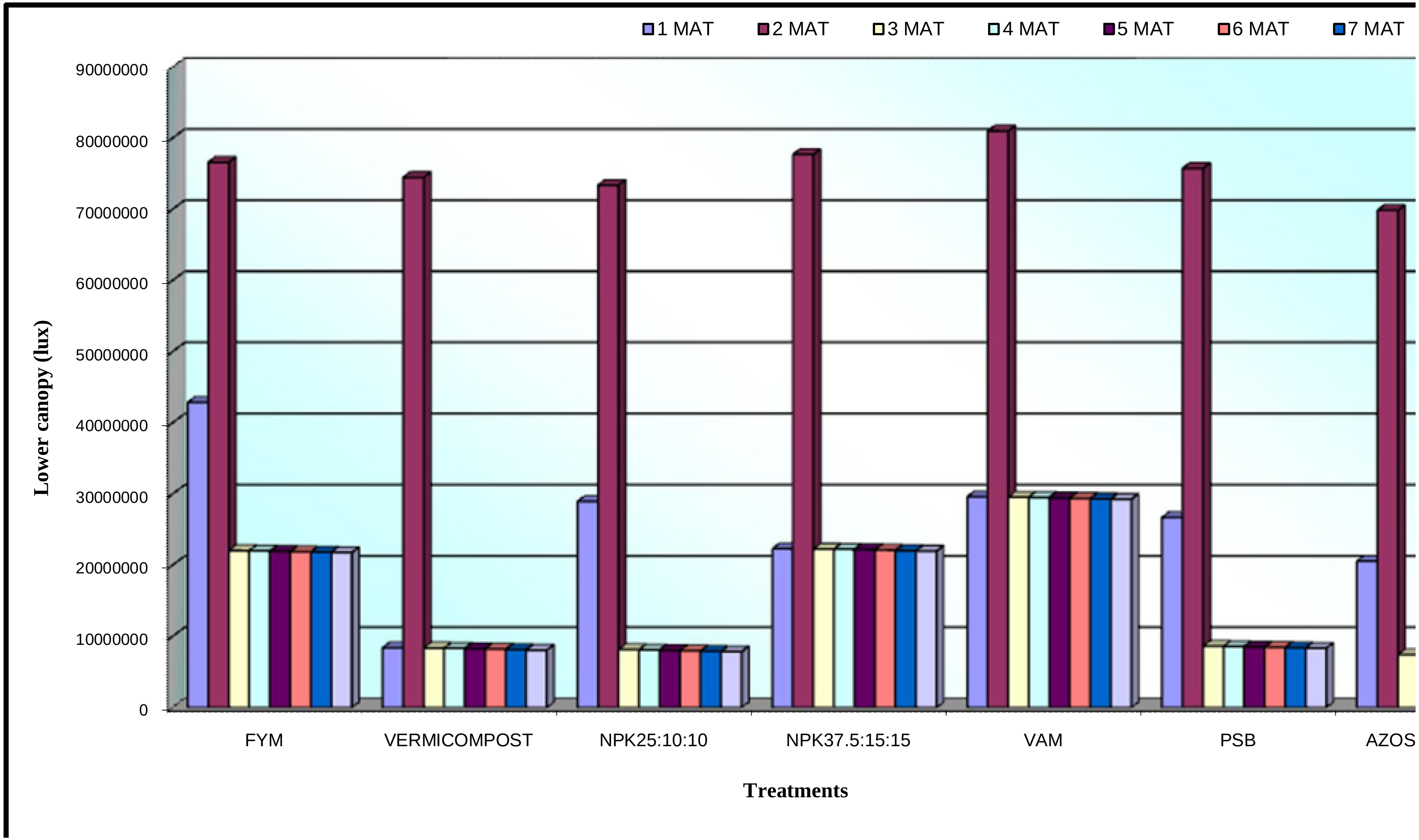
TREATMENTS	1 MAT (11.30 am) *10000 lux	2 MAT (12 am) *10000 lux	3 MAT (11.30 am) * 50000 lux	4 MAT (11 am) * 50000 lux	5 MAT (9.30 am) * 50000 lux	6 MAT (11.00 am) * 50000 lux	7 MAT (10.15 am) * 50000 lux	8 MAT (11.40 am) * 50000 lux
ORGANIC MANURES								
FYM	44593888.89	76367592.59	33929351.85	33889891.85	33821178.52	33763173.35	33703389.35	33643605.35
VERMICOMPOST	7111666.667	68058333.33	7086666.667	7051314.667	6994839.667	6927656.5	6856422.5	6785188.5
S.Em±	4470586.363	1838900.653	4070062.836	4070181.692	4069964.625	4070347.483	4070741.585	4071135.876
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
INORGNIC FERTILIZER								
$NPK_{25:10:10}$	22180370.37	74901851.85	22151203.7	22111743.7	22047620.87	21983498.04	21919134.04	21854770.04
$NPK_{37.5:15:15}$	29525185.19	69524074.07	18864814.81	18829462.81	18768397.31	18707331.81	18640677.81	18574023.81
S.Em±	5475327.72	2252184.144	4984788.585	4984934.152	4984668.301	4985137.204	4985619.879	4986102.785
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
BIO-FERTILIZER								
VAM	26407222.22	78398611.11	26375972.22	26334458.22	26268806.72	26207741.22	26144522.22	26081303.22
PSB	44163611.11	70655555.56	28156111.11	28120759.11	28059693.61	27994042.11	27927388.11	27860734.11
AZOSPIRILLUM	6987500	67584722.22	6991944.444	6956592.444	6895526.944	6834461.444	6767807.444	6701153.444
S.Em±	4470586.363	1838900.653	4070062.836	4070181.692	4069964.625	4070347.483	4070741.585	4071135.876
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
INTERACTIONS ORGANIC×INORGANIC								
S.Em±	7743282.72	3185069.361	7049555.622	7049761.486	7049385.516	7050048.644	7050731.249	7051414.182
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
ORGANIC×BIO-FERTILIZER								
S.Em±	6322363.866	2600598.243	5755938.063	5756106.15	5755799.171	5756340.613	5756897.958	5757455.571
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
INORGANIC×BIO-FERTILIZER								
S.Em±	7743282.72	3185069.361	7049555.622	7049761.486	7049385.516	7050048.644	7050731.249	7051414.182
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
ORGANIC×INORGANIC×BIO-FERTILIZER								
S.Em±	10950655.44	4504368.287	9969577.17	9969868.305	9969336.603	9970274.408	9971239.757	9972205.571
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS



1 MAT
2 MAT
3 MAT
4 MAT
5 MAT
6 MAT
7 MAT
Middle canopy (lux)
80000000
70000000
60000000
50000000
40000000
30000000
20000000
10000000
0
FYM
VERMICOMPOST
NPK25:10:10
NPK37.5:15:15
VAM
PSB
AZOS
Treatments

Table 8c. Effect of organic manures, inorganic fertilizers and bio-fertilizers on light interception (lux) on lower Canopy in *Santalum album* at different months after treatment

TREATMENTS	1 MAT (11.30 am) *10000 lux	2 MAT (12 am) *10000 lux	3 MAT (11.30 am) * 50000 lux	4 MAT (11 am) * 50000 lux	5 MAT (9.30 am) * 50000 lux	6 MAT (11.00 am) * 50000 lux	7 MAT (10.15 am) * 50000 lux	8 MAT (11.40 am) * 50000 lux
ORGANIC FERTILIZER								
FYM	42864257.59	76604629.63	22058424.26	22018964.26	21950250.93	21892245.76	21832461.76	21772677.76
VERMICOMPOST	8397962.963	74489814.81	8372962.963	8337610.963	8281135.963	8213952.796	8142718.796	8071484.796
S.Em±	4209846.369	1271038.258	3147408.076	3147494.624	3147357.785	3147627.558	3147893.816	3148160.346
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
INORGNIC FERTILIZER								
$NPK_{25:10:10}$	28955370.37	73393518.52	8149537.037	8110077.037	8045954.204	7981831.37	7917467.37	7853103.37
$NPK_{37.5:15:15}$	22306850.19	77700925.93	22281850.19	22246498.19	22185432.69	22124367.19	22057713.19	21991059.19
S.Em±	5155987.75	1556697.588	3854771.899	3854877.898	3854710.306	3855040.709	3855366.807	3855693.238
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
BIO-FERTILIZER								
VAM	29601664.17	81008333.33	29570414.17	29528900.17	29463248.67	29402183.17	29338964.17	29275745.17
PSB	26722222.22	75761111.11	8627222.222	8591870.222	8530804.722	8465153.222	8398499.222	8331845.222
AZOSPIRILLUM	20569444.44	69872222.22	7449444.444	7414092.444	7353026.944	7291961.444	7225307.444	7158653.444
S.Em±	4209846.369	1271038.258	3147408.076	3147494.624	3147357.785	3147627.558	3147893.816	3148160.346
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
INTERACTIONS ORGANIC×INORGANIC								
S.Em±	7291667.804	2201502.841	5451470.7	5451620.605	5451383.593	5451850.854	5452312.026	5452773.669
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
ORGANIC×BIO-FERTILIZER								
S.Em±	5953621.831	1797519.543	4451107.187	4451229.584	4451036.065	4451417.582	4451794.127	4452171.057
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
INORGANIC×BIO-FERTILIZER								
S.Em±	7291667.804	2201502.841	5451470.7	5451620.605	5451383.593	5451850.854	5452312.026	5452773.669
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
ORGANIC×INORGANIC×BIO-FERTILIZER								
S.Em±	10311975.5	3113395.175	7709543.798	7709755.796	7709420.612	7710081.417	7710733.613	7711386.475
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS


1 MAT
2 MAT
3 MAT
4 MAT
5 MAT
6 MAT
7 MAT
90000000
80000000
70000000
60000000
50000000
40000000
30000000
20000000
10000000
0
Lower canopy (lux)
FYM
VERMICOMPOST
NPK25:10:10
NPK37.5:15:15
VAM
PSB
AZOS
Treatments

The interaction combination of organic manures and inorganic fertilizers and also in organic and bio-fertilizers did not have any significant effect on soil pH. In the interaction combination of inorganic fertilizer and bio-fertilizer application there was a significant effect on soil pH. Significantly maximum pH was noticed in $NPK_{25:10:10\ g/tree}$ X VAM treatment (5.99), followed by $NPK_{37.5:15:15\ g/tree}$ X PSB treatment (5.89) and minimum in $NPK_{37.5:15:15\ g/tree}$ X VAM treatment (5.58) (Table 9a).

In the combination interaction of organic, inorganic and bio-fertilizer application there was no significant effect on soil pH.

4.2.2 Electrical conductivity (dSm^{-1})

The data pertaining to electrical conductivity of soil after 8 months as influenced by integrated nutrient management are given in Table 9.

The application of organic manures did not have any significant effect on electrical conductivity.

Among the fertilizer levels, there was significant variation in electrical conductivity. The highest was noticed in $NPK_{37.5:15:15g/tree}$ (0.05 dSm^{-1}) and the lowest were noticed in $NPK_{25:10:10\ g/tree}$ (0.03 dSm^{-1}).

The application of bio-fertilizers did not have any significant effect on electrical conductivity. However, the maximum EC was noticed in PSB (0.05 dSm^{-1}) followed by 0.04 dSm^{-1} in VAM and Azospirillum respectively.

In interaction combination *i.e.* organic manures and inorganic fertilizer application, organic manures + bio-fertilizer application and inorganic fertilizers + bio-fertilizer application, there was no significant effect on electrical conductivity.

In the combination interaction of organic, inorganic and bio-fertilizer application there was no significant effect on electrical conductivity.

4.2.3 Soil organic carbon (%)

The Organic carbon content of the soil after 8 months of treatments as influenced by integrated nutrient management are presented in Table 9.

The application of organic manures did not have any significant effect on soil organic carbon. However, the highest organic carbon was noticed in FYM (1.24%) and lowest in Vermicompost (1.19%).

Among the fertilizer levels also, there was no significant variation in soil organic carbon. However, the highest was noticed in $NPK_{37.5:15:15\ g/tree}$ (1.26%) and the lowest were noticed in $NPK_{25:10:10\ g/tree}$ (1.17%).

The application of bio-fertilizers did not have any significant effect on soil organic carbon. However, the maximum organic carbon was noticed in PSB (1.23%) followed by VAM (1.22%) and minimum in Azospirillum (1.20%).

In interaction combination *i.e.* organic manures and inorganic fertilizer application, organic manures + bio-fertilizer application and inorganic fertilizers + bio-fertilizer application, there was no significant effect on soil organic carbon.

In the combination interaction of organic, inorganic and bio-fertilizer application there was no significant effect on soil organic carbon.

4.3 Available Nutrient status of soil

4.3.1 Available nitrogen

Available nitrogen in soil after 8 months as influenced by integrated nutrient management in *Santalum album* is presented in Table 10. Before start of the experiment available nitrogen in soil was 176 kg/ha.

The organic manures had a significant influence on the build-up of nitrogen in soil. The significantly maximum available nitrogen was found in plants receiving vermicompost *i.e.,* 188.08 kg/ha. Compared to plants receiving FYM *i.e.,* 149.87 kg/ha.

Table 9. Soil pH, Electrical conductivity and Organic carbon as influenced by integrated nutrient management in *Santalum album*

TREATMENTS	Soil pH	EC (dSm^{-1})	OC (%)
Organic manures			
FYM	5.78	0.04	1.24
VERMICOMPOST	5.81	0.04	1.19
S.Em±	0.05	0.01	0.03
CD at 5%	NS	NS	NS
Inorganic fertilizer			
$NPK_{25:10:10}$	5.81	0.03	1.17
$NPK_{37.5:15:15}$	5.78	0.05	1.26
S.Em±	0.06	0.01	0.04
CD at 5%	NS	0.01	NS
Bio-fertilizer			
VAM	5.79	0.04	1.22
PSB	5.85	0.05	1.23
AZOSPIRILLUM	5.75	0.04	1.20
S.Em±	0.05	0.01	0.03
CD at 5%	NS	NS	NS
INTERACTIONS Organic fertilizer × Inorganic fertilizer			
S.Em±	0.08	0.01	0.06
CD at 5%	NS	NS	NS
Organic fertilizer × Bio-fertilizer			
S.Em±	0.06	0.01	0.05
CD at 5%	NS	NS	NS
Inorganic × Bio-fertilizer			
S.Em±	0.08	0.01	0.06
CD at 5%	0.22	NS	NS
Organic ×Inorganic × Bio-fertilizer			
S.Em±	0.11	0.01	0.09
CD at 5%	NS	NS	NS

Table 9a. Interaction effect of Inorganic fertilizer and Bio-fertilizer on soil pH in *Santalum album*

Treatments	Soil pH
$NPK_{25:10:10}$ X VAM	5.99
$NPK_{25:10:10}$ X PSB	5.81
$NPK_{25:10:10}$ X AZOS.	5.63
$NPK_{37.5:15:15}$ X VAM	5.58
$NPK_{37.5:15:15}$ X PSB	5.89
$NPK_{37.5:15:15}$ X AZOS.	5.86
S.Em±	0.08
CD at 5%	0.22

Table 10. Available Nitrogen, Phosphorus and Potassium (kg/ha) as influenced by integrated nutrient management in *Santalum album*

TREATMENTS	Available N (kg/ha)	Available P2O5 (kg/ha)	Available K2O (kg/ha)
Organic fertilizer			
FYM	149.87	29.73	152.65
VERMICOMPOST	188.08	39.13	168.01
S.Em±	2.04	0.47	0.65
CD at 5%	5.99	1.37	1.92
Inorganic fertilizer			
$NPK_{25:10:10}$	157.28	32.34	155.99
$NPK_{37.5:15:15}$	180.68	36.52	164.67
S.Em±	2.50	0.57	0.80
CD at 5%	7.33	1.67	2.35
Bio-fertilizer			
VAM	175.81	33.01	163.28
PSB	162.34	36.20	156.89
AZOSPIRILLUM	168.78	34.08	160.83
S.Em±	2.04	0.47	0.65
CD at 5%	5.99	1.37	1.92
INTERACTIONS			
Organic fertilizer × Inorganic fertilizer			
S.Em±	3.54	0.81	1.13
CD at 5%	10.37	NS	NS
Organic fertilizer × Bio-fertilizer			
S.Em±	2.89	0.66	0.93
CD at 5%	NS	NS	NS
Inorganic × Bio-fertilizer			
S.Em±	3.54	0.81	1.13
CD at 5%	NS	NS	3.33
Organic ×Inorganic × Bio-fertilizer			
S.Em±	5.00	1.14	1.60
CD at 5%	NS	NS	NS

The inorganic fertilizers had a significant influence on the build-up of nitrogen in soil. The significantly maximum available nitrogen was found in $NPK_{37.5:15:15\ g/tree}$ *i.e.,* 180.68 kg/ha compared to $NPK_{25:10:10g/tree}$ *i.e.,* 157.28 kg/ha.

The bio-fertilizers had a significant influence on the build-up of nitrogen in soil. The significantly maximum available nitrogen was found in VAM *i.e.,* 175.81 kg/ha followed by Azospirillum *i.e.,* 168.78 kg/ha. And Minimum was found in PSB *i.e.,* 162.34 kg/ha.

The interaction combination of organic manures and inorganic fertilizers showed significant effect on available nitrogen. Significantly maximum available nitrogen (196.72 kg/ha) was found in Vermicompost X $NPK_{37.5:15:15g/tree}$ followed by Vermicompost X $NPK_{25:10:10g/tree}$ (179.44 kg/ha) and minimum (135.11 kg/ha) in FYM X $NPK_{25:10:10g/tree}$ (Table 10a).

In organic and bio-fertilizers and in the interaction combination of inorganic fertilizer and bio-fertilizer application there was no significant effect on available nitrogen.

In the combination interaction of organic, inorganic and bio-fertilizer application there was no significant effect on available nitrogen.

4.3.2 Available P_2O_5

Available P_2O_5 in soil after 8 months as influenced by integrated nutrient management in *Santalum album* is presented in Table 10. Before start of the experiment available P_2O_5 in soil was 23.5 kg/ha.

The organic manures had a significant influence on the available phosphorus in soil. The maximum available P_2O_5 was found in vermicompost *i.e.,* 39.13 kg/ha compared to FYM *i.e.,* 29.73 kg/ha.

The inorganic fertilizers had a significant influence on the P_2O_5 in soil. The maximum available P_2O_5 was found in $NPK_{37.5:15:15\ g/tree}$ *i.e.,* 36.52 kg/ha. Minimum was found in $NPK_{25:10:10g/tree}$ *i.e.,* 32.34 kg/ha.

The bio-fertilizers had a significant influence on the P_2O_5 in soil. The maximum available P_2O_5 was found in PSB *i.e.,* 36.20 kg/ha followed by Azospirillum *i.e.,* 34.08 kg/ha. And Minimum was found in VAM *i.e.,* 33.01 kg/ha.

The interaction combination of organic manures and inorganic fertilizers showed non-significant effect on available P_2O_5. In organic and bio-fertilizers application also showed a non-significant effect on available P_2O_5. In the interaction combination of inorganic fertilizer and bio-fertilizer application there was no significant effect on available P_2O_5.

In the combination interaction of organic, inorganic and bio-fertilizer application there was no significant effect on available P_2O_5.

4.3.3 Available K_2O

Available K_2O in soil after 8 months as influenced by integrated nutrient management in *Santalum album* is presented in Table 10. Before start of the experiment available K_2O in soil was 136 kg/ha.

The organic manures had a significant influence on the K_2O in soil. The maximum available K_2O was found in vermicompost *i.e.,* 168.01 kg/ha. Minimum was found in FYM *i.e.,* 152.65 kg/ha.

The inorganic fertilizers had a significant influence on the available K_2O in soil. The maximum available K_2O was found in $NPK_{37.5:15:15\ g/tree}$ *i.e.,* 164.67 kg/ha. Minimum was found in $NPK_{25:10:10g/tree}$ *i.e.,* 155.99 kg/ha.

The bio-fertilizers had a significant influence on the available K_2O in soil. The maximum available K_2O was found in VAM *i.e.,* 163.28 kg/ha followed by Azospirillum *i.e.,* 160.83 kg/ha. And Minimum was found in PSB *i.e.,* 156.89 kg/ha.

The interaction combination of organic manures and inorganic fertilizers and in the interaction combination of organic and bio-fertilizers there was no significant effect on available K_2O.

In the interaction combination of inorganic fertilizer and bio-fertilizer application there was a significant effect on available K_2O. The significantly maximum available K_2O (166.97 kg/ha) was found in $NPK_{37.5:15:15g/tree}$ X VAM treatment followed by $NPK_{37.5:15:15g/tree}$ X Azospirillum (164.97 kg/ha) Minimum available K_2O (151.70 kg/ha) was found in $NPK_{25:10:10g/tree}$ X PSB treatment (Table 10b). In the combination interaction of organic, inorganic and bio-fertilizer application there was no significant effect on available K_2O.

Table 10a. Interaction effect of Organic fertilizer and inorganic fertilizer on available N (kg/ha) in *Santalum album*

Treatments	Available N (kg/ha)
FYM X $NPK_{25:10:10g/tree}$	135.11
FYM X $NPK_{37.5:15:15g/tree}$	164.63
VERMI. X $NPK_{25:10:10g/tree}$	179.44
VERMI. X $NPK_{37.5:15:15g/tree}$	196.72
S.Em±	3.54
CD at 5%	10.37

Table 10b. Interaction effect of Inorganic fertilizer and Bio-fertilizer on available K_2O (kg/ha) in *Santalum album*

Treatments	Available K_2O (kg/ha)
$NPK_{25:10:10}$ X VAM	159.60
$NPK_{25:10:10}$ X PSB	151.70
$NPK_{25:10:10}$ X AZOS.	156.68
$NPK_{37.5:15:15}$ X VAM	166.97
$NPK_{37.5:15:15}$ X PSB	162.07
$NPK_{37.5:15:15}$ X AZOS.	164.97
S.Em±	1.13
CD at 5%	3.33

DISCUSSION

Sandal wood (*Santalum album* L.) is a highly valuable tree for its medicinal value and its demand in the highly preferred scented oil. Its cultivation is being expanded in the countries like Australia, Sri Lanka and Singapore on commercial scale in view of demand and supply gap. In India, the present production is less than 90 Tonnes, in which more than 60 Tonnes of oil required annually and more than 30 Tonnes of Sandalwood oil will be exported to other countries. Although demand for Sandalwood and oil is increasing, supplies are declining and prices increasing (Ananthapadmanabha, 2000). Plantations based on high-quality planting material are essential in order to meet the demand and preserve some of the natural *Santalum album* resource.

Soil, nutrients and light are the three important factors which influence growth and productivity of trees. Among these resources, nutrients are most essential factor for plant growth. It is well known that application of manures and fertilizers have significant impact on growth of plants. The proper management of nutrients helps to reduce the nutrient losses from soil and improve the nutrient availability for plant growth which in turn, boosts the productivity of land and plants.

The present study was conducted during the year 2012-13 in the farmer's field in Santholli village, near Dasanakoppa of Uttar Kannada district, hill zone (Zone-9) of Karnataka. The finer details of the experiment on "Effect of integrated nutrient management on growth of *Santalum album* in horti-silvi system" are discussed in this chapter. The literature concerning to the study on *Santalum album* is very meagre. Hence relative findings have been quoted wherever necessary.

The meteorological data of the experimental site showed that the mean annual rainfall (2002-2011) of 10 years was 1401.67 mm and the annual rainfall over the experiment period was 922.20 mm thus there was deficient rainfall of 478.80 mm over the 10 year average rainfall value; with maximum rainfall in month of August (281.60 mm) and minimum in the month of December (1.40 mm) which was almost negligible. The highest mean monthly maximum temperature was recorded in the month of April (33°C) and lowest in the month of August (25.4°C) whereas highest and lowest mean monthly minimum temperature was recorded in May (23.2°C) and January (15.7°C) respectively.

5.1 The effect of organic manures, inorganic fertilizers and bio-fertilizers on growth attributes of *Santalum album*

5.1.1 Plant height and collar diameter

The present study reveals that, application of organic manures influenced the plant height significantly. Vermicompost @ 1 kg/tree influenced the plant height and collar diameter (from 1 to 8 MAT) significantly at all the intervals (Table 3 and 4). Vermicompost @ 1 kg/tree registered higher plant height (2.94 m) and collar diameter (5.99 cm) at 8 MAT compared to that with other treatments. Higher plant height and collar diameter in vermicompost @ 1 kg/tree might be due to vermicompost had the highest levels of total N, total P and narrowest ratio of C/N and C/P, suggesting superior mineralization of organic forms of N and P and improved the organic matter content of soil, available nutrients of soil that might have increased the plant height and collar diameter. These results are in line with studies conducted by Krishnan (2001) on *Simaruba glauca*, Chandrakhanth (2011) on *Eucalyptus pellita,* Mohammad and Asgharipour (2012) on *Plantago ovata,* Rao and Singh (1985) on *Casuarina equisetifolia* and Sungavanum *et al.* (1998) on *Tectona grandis*.

Fertilizer application influenced the plant height and collar diameter of *Santalum album*. Among fertilizers treatments, application of N, P_2O_5, K_2O 37.5:15:15 g/tree recorded significantly higher height (Table 3) and collar diameter (Table 4) compared to N, P_2O_5, K_2O 25:10:10 g/tree. The increased plant height might be due to application of optimum quantity of fertilizers it might influenced chlorophyll formation in the plants, which lead to improve the photosynthetic activity resulted in vigorous vegetative growth and development of plant. Mutanal (1998) found that application of 200:100:200 N, P_2O_5, K_2O in kg/ha reported to be optimum fertilizers dose for second year to attain maximum height growth in teak. The increased collar diameter of *Acacia auriculiformis* was noticed mainly due to the exogenous application of fertilizers. In the same way the results are in conformity with Turvey (1996) in *Acacia mangium*, Mutanal (1998) in teak and Lamani *et al.* (2001) in *Acacia auriculiformis.*

Plant height and collar diameter did not vary significantly due to application of bio-fertilizers till 3 MAT and 4 MAT respectively. There was a significant difference after 4 MAT in plant height and 5 MAT in collar diameter. This has been probably due to the slow and continuous release of nutrients in the initial stages. Among the bio-fertilizers, VAM recorded significantly higher plant height (2.81 m) and collar diameter (5.86 cm) at 8 MAT. This might be due to VAM is an endomycorrizae which translocate soil from the vesicles to the plants directly. The applied phosphorus is directly translocate to plants which help in better growth. This was followed by Azospirillum. Least plant height and collar diameter was recorded in PSB *i.e.,* 2.65 m plant height and 5.76 cm of collar diameter. These results are in line with studies conducted by Nagaveni *et al.* (2001) in *Santalum album*, Brahmi *et al.* (2010) reported that the minimum of plant height and collar diameter was recorded in control *i.e.*, 55.65 cm and 15.93 mm respectively after 8 months of application of treatments. Higher plant height and collar diameter was recoded in *Acacia catechu* seedlings when bio-fertilizers used in integrated manner with chemical fertilizers.

In organic manures and bio-fertilizer application, the plant height increased significantly at 3 MAT onwards (Table 3a). It might be due to slow and continuous release of nutrients by organic manure and bio-fertilizer. These together also ensures the release of micronutrients, increase the soil organic carbon and positively affects the soil physical properties. These results are in line with studies conducted by Brahmi *et al.* (2010).

In inorganic and bio-fertilizer interaction, plant height and collar diameter showed significantly variation at different months after treatments (Table 3b and 4a). The maximum plant height recorded in $NPK_{37.5:15:15\ g/tree}$ X VAM (2.90 m) followed by $NPK_{37.5:15:15\ g/tree}$ X Azospirillum treatment (2.88 m) and least was noticed in $NPK_{25:10:10\ g/tree}$ X PSB (2.34 m). The maximum collar diameter recorded in $NPK_{37.5:15:15\ g/tree}$ X VAM (5.97 cm) followed by $NPK_{37.5:15:15\ g/tree}$ X Azospirillum treatment (5.84 cm) and least was noticed in $NPK_{25:10:10\ g/tree}$ X PSB (5.69 cm). This is attributable to higher nutrient availability both by inorganic fertilizers and later on bio-fertilizers. These results are in line with studies conducted by Ananthapadmanabha *et al*. (1998) in *Tectona grandis*.

5.1.2 Crown diameter and number of branches

Organic manures significantly increased the crown diameter and number of branches (Table 5 and 7). The crown diameter (1.93 m) and number of branches (39.62) were significantly higher in plants receiving vermicompost @ 1 kg per tree compared to FYM. It might be due to application of vermicompost which might have the availability of nutrients in turn favoured the growth of *Santalum album*. Higher quantity of nitrogen in applied manure might have increased the chlorophyll content in the plants, which led to increased photosynthetic activity resulting in vigorous vegetative growth and development of plant. Banerjee (1973) reported that the increase in all growth parameter is mainly due to exogenous application of manures. These results are in conformity with the Lamani *et al*. (2001), Turvey (1996) in *Acacia mangium* and Prasad *et al*. (1984) in *Eucalyptus grandis*.

Inorganic manures showed significant influence crown diameter and number of branches of *Santalum album*. Among fertilizers treatments 37.5:15:15 N, P_2O_5, K_2O kg/ha recorded significantly higher crown diameter and number of branches. The increased crown diameter increment probably might be due to application of optimum quantity of N, P_2O_5, K_2O fertilizers. Optimum quantity of nitrogen in applied fertilizers might have increased the chlorophyll content in the plants, which led to increased photosynthetic activity resulting in vigorous vegetative growth and development of plant. Banerjee (1973) reported that increased number of branches can be attributed to increased availability of nutrients might have resulted in increased production of photosynthetic and their translocation into branches and leaves. These results are in conformity with the findings of Deswal *et al.* (2001); Hulikatti and Madiwalar (2011) who reported that the number of branches per plant of *Acacia nilotica* increased linearly with increasing level of nitrogen as well as phosphorus. The increase in all growth parameter is mainly due to exogenous application of NPK. These results are also in conformity with the Lamani *et al.* (2001); Turvey (1996) in *Acacia mangium* and Prasad *et al.* (1984) in *Eucalyptus grandis*. In addition to these Mutanal (1998) has suggested that the application of 100:50:100 N, P_2O_5, K_2O kg/ha is optimum fertilizers dose for first year of teak growth in his study. Crown diameter increment was significant this might be attributed to the fact that the dissolution of fertilizers and subsequent absorption of dissolved nutrients by plants may require considerable time where applied nutrients immediately absorbing plants. These results are in agreement with Deya (1995) who observed better growth of *Acacia cyclops* with higher dose of fertilizers and also with the findings of Prasad *et al.* (1986) in *Eucalyptus grandis.*

In the case of bio-fertilizers application, there was no significant difference at any stage of the growth in crown diameter, but number of branches showed significant difference at different stages of growth. The significantly higher numbers of branches were found in VAM (37.96), followed by

Azospirillum (36.90) and least was found in PSB (36.10). This might be due to increased P_2O_5 availability in VAM strengthening the plant structure.

In interaction combination *i.e.* organic manures and inorganic fertilizer levels, there was no significant difference at any stage of growth in both crown diameter and number of branches.

In organic manures and bio-fertilizer application, the crown diameter showed significant difference at different stages of growth (Table 5a). The maximum crown diameter was recorded in Vermicompost X VAM (2.03 m) followed by Vermicompost X PSB (1.89 m) and least was found in FYM X PSB treatment (1.72 m) and there was no significant difference in number of branches. This is attributable to the higher nutrient availability by both inorganics and bio-fertilizers.

In inorganic and bio-fertilizer combination interaction, there was no significant difference at any stage growth in crown diameter but there was a significant variation in number of branches (Table 7a). The highest number of branches were found in $NPK_{37.5:15:15\ g/tree}$ X VAM (39.17) followed by $NPK_{37.5:15:15\ g/tree}$ X PSB (37.80) and least were found in $NPK_{25:10:10\ g/tree}$ X PSB (34.40). These results are agreement with Gupta *et al.* (2011) in black henbane.

5.1.3 Basal area (cm^2)

Basal area increased significantly with application of organic manures at different intervals of growth (Table 6). The significantly higher basal area (28.16 cm^2) was found in vermicompost @ 1 kg per tree compared to FYM @ 2 kg per tree (24.96 cm^2). It is due to higher growth, better plant structure as shown by plant height and collar diameter.

In the case of inorganic fertilizers application, the basal area showed significant increases at different growth stages. The significantly higher basal area was found in $NPK_{37.5:15:15\ g/tree}$ (27.17 cm^2) compared to $NPK_{25:10:10\ g/tree}$ (25.96 cm^2). This might be due to the quick supply of mineral nutrients by the inorganic fertilizers at the peak period of growth of the plant. These findings are similar with Mutanal *et al.* (2002) in *Tectona grandis,* observed that different doses of inorganic fertilizers increased the biomass production, plant height, basal area and also with the findings of Kumari *et al.* (2002) in *Eucalyptus tereticornis*.

In the case of bio-fertilizers application, there was no significant difference at initial stages of the growth. But after the 5 MAT, basal area showed significantly higher effect in *Santalum album*. The maximum basal area was found in VAM (26.98 cm^2) followed by Azospirillum (26.68 cm^2) and least was recorded in PSB (26.08 cm^2). This might be due to the colonization and action of bio-fertilizers may take some initial time. After it will have the effect on nutrient mobilization. Same trend was observed by Subramanian *et al.* (1998), where in no significant effect of the bio-fertilizers when applied separately for *Tectona grandis*.

There was no significant difference in organic manures and inorganic fertilizer application, organic manures and bio-fertilizer application at any stage of growth.

In inorganic fertilizers and bio-fertilizer application showed significantly higher basal area (Table 6a) in $NPK_{37.5:15:15\ g/tree}$ X VAM (27.99 cm^2) followed by $NPK_{37.5:15:15\ g/tree}$ X Azospirillum (26.79 cm^2) and least was recorded in $NPK_{25:10:10\ g/tree}$ X PSB treatment (25.44 cm^2). This is attributable to the higher nutrient availability by both inorganics and bio-fertilizers. These findings are similar with Paroha *et al*. (2009) in *Tectona grandis.*

In the combination interaction of organic, inorganic and bio-fertilizer application there was no significant difference at any stage of growth.

5.1.5 Light interception measurement:

The effect of organic, inorganic and bio-fertilizer application to the light interception measurement has no significant effect in upper canopy, middle canopy and lower canopy. In the interaction effect of organic and bio-fertilizer, inorganic and bio-fertilizer, organic and inorganic fertilizers have also found to be non-significant effect throughout the observation period.

5.2 Chemical properties of soil

5.2.1 Soil pH

The effect of integrated nutrient management on soil pH after all the different growth stages (Table 9) is discussed below.

For the soil pH, the effect of organic, inorganic and bio-fertilizer application were statistically similar to each other. Among the organic manure treatments vermicompost (5.81) showed highest pH, compared to FYM (5.78) this was due to moderating effect of organic manures and buffering property leading towards neutral pH. In the inorganic fertilizer treatment $NPK_{25:10:10g/plant}$ (5.81) recorded highest pH compared to $NPK_{37.5:15:15\ g/plant}$ (5.78). This was because of higher concentration of acidic ions, in response to higher fertilizer dose. In the bio-fertilizer treated plants highest was recorded in PSB (5.85) followed by VAM (5.79) and Azospirillum (5.75). The interaction effect of organic and inorganic, inorganic and bio-fertilizer all other interaction, except inorganic and bio-fertilizer were statistically similar each other.

5.2.2 Electrical conductivity of soil (EC)

Electrical conductivity, values of soil were statistically similar in all the treatments and interaction, except inorganic fertilizer. Individual treatments or combination of these treatments EC ranged from 0.01 to 0.05 dSm^{-1} (Table 9). However among the individual treatments highest EC was recorded in $NPK_{37.5:15:15\ g/plant}$ (0.05), this was due on account of higher availability of plant nutrients due to higher dosage of inorganic fertilizers used. In all the combination same EC value was recorded (0.01). This indicates there is no salts accumulation in the soil this might be due to salts were leached out from the soil body as reported by Bajpai *et al.* (1980).

5.2.3 Organic carbon content of soil

Organic carbon is an important soil chemical parameter as it is important for the soil organic matter and also for maintaining C/N ratio of soil. The effect of organic, inorganic and bio-fertilizers did not influence organic carbon content of soil (Table 9). Although there was increase of organic carbon from 1.17 to 1.24 per cent (Table 9) over initial (1.11%), (Table 2) the values indicates that all the treatments and their interaction were statistically similar to each other.

5.3 Nutrient status of soil

5.3.1 Available Nitrogen

Nitrogen is the most important macronutrient needed for plant growth and development as it forms chlorophyll, amino acids, proteins, alkaloids and protoplasm *etc.* Available nitrogen increased significantly with the application of organic manures, inorganic fertilizers and bio-fertilizers (Table 10). Among the organic manures highest available nitrogen was found in vermicompost (188.08 kg/ha), when compared to FYM (149.87 kg/ ha). It might be due gradual decomposition and subsequent release of mineral nutrients by organic manures resulting in increases of the nitrogen content (Muthuvel *et al.*, 1977). Among the inorganic fertilizers, $NPK_{37.5:15:15\ g/tree}$ (180.68 kg/ha) recorded higher nitrogen compared to $NPK_{25:10:10\ g/tree}$ (157.28 kg/ha). It might be due to higher doses of nitrogen increases the available nitrogen in the soil. Among the bio-fertilizers, VAM (175.81 kg/ha) showed significantly more nitrogen followed by Azospirillum (168.78 kg/ha) and least was recorded in PSB (162.34 kg/ha). This might be due to slow and continuous supply of available nutrients through VAM increases the available nitrogen.

In the interaction treatments, only organic and inorganic combination was significantly different, and recorded nitrogen was found in vermicompost X $NPK_{37.5:15:15\ g/tree}$ treatment (196.72 Kg/ ha) and least was found in FYM X $NPK_{25:10:10\ g/tree}$ (135.11 Kg/ha). This might be due to the increased availability of nitrogen due to synergistic combination of organic and inorganic source of nutrients. Rest other interaction treatments were statistically at par to each other.

5.3.2 Available phosphorus

Phosphorous is one of the important macronutrient needed for the much growth and vigor of plants, it makes 0.10 to 0.50 per cent of the dry weight of the plant. Therefore, plants which cannot absorb adequate quantities of phosphorus from the soil have small root system and leaves, and their growth is stunted. Among the individual treatments there exists significant difference among the sub-components of the treatments; whereas among the combination of various kinds of treatment all of them were statistically at par with each other. Compared to initial phosphorus level (23.50 kg/ha), there was increase in the phosphorous level. Highest available phosphorus was recorded, among organic manures, vermicompost (39.13 kg/ha), inorganic fertilizer, $NPK_{37.5:15:15\ g/tree}$ (36.52 Kg/ha) and bio-fertilizer, PSB (36.20 kg/ha) (Table 10). This was because of availability of immobilized phosphorous in the soil due to activity of micro-organisms and also due to the influence of organic manure in increasing the available phosphorous through complexing of cations like Ca^{2+}, Mg^{2+}, Fe^{3+} and Al^{3+} which are mainly responsible for fixation of phosphorous (Kardas, 1964).

5.3.3 Available potassium

Potassium is another important macronutrient which imparts vigour and resistance from disease and pest to plants. Potassium level as influenced by potassium content in soil by the application of organic manures, inorganic fertilizer and bio-fertilizer combination are shown in Table 10. The results obtained are on similar lines with the available phosphorous. Among the individual treatments there exists significant difference among the sub-components of the treatments; whereas among the combination of various kinds of treatment all of them were statistically at par with each other. Within the individual treatment organic source vermicompost (168.01 kg/ha) recorded highest, in inorganic fertilizers, $NPK_{37.5:15:15g/tree}$ (64.67 kg/ha); whereas in bio-fertilizer, VAM (163.28 kg/ha) recorded highest potassium content in the soil. This might be due to the fact that higher level of potassium resulted in higher availability in soil pool and thereby helped in build-up of potassium over the initial (136.0 kg/ha). It also attributed to the increase in potassium content of the soil might be due to the added fertilizers. Further, slower mineralization rate of these nutrients might also be a contributing factor for higher accumulation of nutrients in the soil. These results are in conformity with the findings of Narahari (1999) and Devegowda (1997).

SUMMARY AND CONCLUSIONS

Integrated Nutrient Management (INM) on growth of *Santalum album* is important to understand and to establish successful plantation, it not only minimizes the economic and ecological wastage on other resources but contribute significantly towards the optimization of resources and productivity without hampering the soil health. To overcome this problem, a field experiment was carried out to study the effect of integrated nutrient management on growth of *Santalum album* during 2012-2013 at Dasanakoppa of Sirsi taluk, Uttara Kannada district. The findings of the experiment are summarized here.

6.1 To assess the effect of various combinations of organic, inorganic and bio-fertilizers on growth attributes of *Santalum album*

The effect of twelve different treatments was imposed in three replications on two and half year sandalwood intercrop of farmer field at Dasanakoppa of Sirsi Taluk, Uttara Kannada district. The individual treatments include organic source FYM (2 kg per tree), vermicompost (1 kg per tree) chemical Fertilizers NPK_{100} (N 56 kg/ha, P 24 kg/ha, K 24 kg/ha), NPK_{150} (N 74 kg/ha, P 36 kg/ha, K 36 kg/ha) and bio-fertilizers VAM + PSB + Azospirillum (100 gm + 100 gm + 100 gm per tree); whereas all these nutrient sources were given in a three combinations in an integrated manner.

6.2 To assess the effect of organic, inorganic and bio-fertilizers on the soil chemical properties

For this objective to access the effect of various treatments on soil chemical properties by measuring various parameters such as soil pH, electrical conductivity (dSm^{-1}), organic carbon (%), available nitrogen (kg/ha), available phosphorus (kg/ha) and available potassium (kg/ha) by taking random samples from all the treatments and replication and tested as per their standard procedure.

The results obtained are summarized in this chapter.

1) Among all the treatments maximum plant height and collar diameter was recorded in the organic manure (vermicompost), inorganic fertilizer of $NPK_{37.5:15:15\ g/tree}$ and bio-fertilizer of VAM at the end of eight months after treatment (8 MAT) and it was recorded to be 2.94 m, 2.80 m and 2.81 m of plant height and 5.99 cm, 5.88 cm and 5.86 cm of collar diameter respectively.

2) In the interaction effect of organic and bio-fertilizer treatment maximum plant height was recorded in treatment vermicompost X PSB (2.95 m). In the interaction effect of inorganic and bio-fertilizer treatment maximum plant height and collar diameter was recorded in $NPK_{37.5:15:15\ g/tree}$ X VAM at the end of 8 MAT *i.e.,* 2.90 m and 5.97 cm respectively.

3) Maximum crown diameter and number of branches per tree was recorded in the organic manure (vermicompost), inorganic fertilizer of $NPK_{37.5:15:15\ g/tree}$ and bio-fertilizer of VAM in all the months and at the end of eight months after treatment (8 MAT) it was recorded to be 1.93 m, 1.90 m and 1.88 m of crown diameter and 39.62, 38.00 and 37.96 number of branches respectively.

4) In the interaction effect of organic and bio-fertilizer treatment maximum crown diameter was recorded in vermicompost X VAM (2.03 m). In the interaction effect of inorganic and bio-fertilizer treatment maximum number of branches were recorded in $NPK_{37.5:15:15\ g/tree}$ X VAM (39.17) at the end of 8 MAT.

5) Maximum Basal area was recorded in the organic manure (vermicompost), inorganic fertilizer of $NPK_{37.5:15:15\ g/tree}$ and bio-fertilizer of VAM in all the months and at the end of eight months after treatment (8 MAT). It was recorded to be 28.16 cm^2, 27.17 cm^2 and 26.98 cm^2 respectively.

6) In the interaction effect of inorganic and bio-fertilizer treatment the maximum basal area was recorded in $NPK_{37.5:15:15g/tree}$ X VAM (27.99 cm^2) at the end of 8 MAT.

7) Maximum light was intercepted in the upper canopy, middle canopy and lower canopy of organic (FYM), inorganic ($NPK_{25:10:10g/tree}$) and bio-fertilizer (PSB) at the end of 8 MAT.

8) The effect of organic, inorganic and bio-fertilizer treatments recorded non-significant effect on soil pH. However, the maximum soil pH was noticed in vermicompost (5.81), $NPK_{25:10:10\ g/tree}$

(5.81) and PSB (5.85) and in the interaction effect of inorganic and bio-fertilizer treatments $NPK_{25:10:10g/tree}$ X VAM (5.99).

9) The effect of organic, inorganic and bio-fertilizer treatments recorded non-significant effect on electrical conductivity of soil.

10) The effect of organic, inorganic and bio-fertilizer treatments recorded non-significant effect on organic carbon content of soil.

11) The available nitrogen in soil differed significantly in all treatments. The maximum available nitrogen was recorded in vermicompost treatment (188.08 kg/ha) followed by $NPK_{37.5:15:15\ g/tree}$ (180.68 kg/ha) and VAM (175.81 kg/ha). In the interaction effect of organic and inorganic fertilizer treatment vermicompost X $NPK_{37.5:15:15g/tree}$ treatment (196.72 kg/ha) recorded maximum available nitrogen

12) The available P_2O_5 differed significantly in the treatments of organic manures, inorganic fertilizer and bio-fertilizer application, the maximum available phosphorous recorded in vermicompost (39.13 kg/ha) followed by $NPK_{37.5:15:15\ g/tree}$ (36.52 kg/ha) and PSB (36.20 kg/ha).

13) The available K_2O differed significantly in the treatments of organic manures, inorganic fertilizer and bio-fertilizer application. The maximum available potassium was recorded in vermicompost (168.01 kg/ha) followed by $NPK_{37.5:15:15\ g/tree}$ (164.67 kg/ha) and VAM (163.28 kg/ha). In the interaction effect of inorganic and bio-fertilizer treatment $NPK_{37.5:15:15\ g/tree}$ X VAM treatment (166.97 kg/ha) recorded maximum available potassium.

From the above results integrated treatment of Organic (Vermicompost), Inorganic (NPK) and bio-fertilizer (VAM) applied at the rate of vermicompost (2 kg/tree) + $NPK_{37.5:15:15\ g/tree}$ + VAM (100 g/tree) proved to be best among all the treatments on account of higher plant height, collar diameter, crown diameter, number of branches, basal area.

Practical utility of the experiment

1. Megre research has been done on cultivation of *Santalum album* in plantations and agroforestry systems. Hence this present study will be benefit for the all cultivators of sandalwood to provide optimum nutrients requirement to promote the growth and yield of particular trees.
2. Integrated nutrient management helps to maximize use of all the available options of source of nutrients and simultaneously the growth and productivity also, which has much more relevance in Indian conditions particularly due to greater number of small land-holding of farmers.
3. Application of vermicompost @ 2 kg/tree along with 74:36:36 N, P_2O_5, K_2O kg/ha and VAM @ 100 g/tree increased the growth of *Santalum album*. Hence it could be adapted to large area to get higher volume.

Future line of work

1. There is need to study whether yearly application of suggested fertilizers is necessary to gain better growth and yield.
2. Effect of organic manures, inorganic fertilizers and bio-fertilizers on wood quality and oil yield need to be studied
3. There is a need for thorough study on effect of nitrogen, phosphorus and potassium fertilizers on growth of *Santalum album* on long term basis.
4. Detailed studies on tree crop interaction are required to quantify the effect of *Santalum album* on the associated main crops.

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EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH OF *Santalum album* L. IN HORTI-SILVI SYSTEM

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ABSTRACT

Integrated Nutrient Management (INM) on growth of *Santalum album* is important to understand and to establish successful plantation, it not only minimizes the economic and ecological wastage on other resources but contribute significantly towards the optimization of resources and productivity without hampering the soil health. Keeping these emerging requirements in mind the present study was conducted at farmer's field, Santholli village of Sirsi taluk during 2012-2013.

The experiment was carried out in two and half year old sandalwood plantation in a factorial randomised complete block design with 12 treatments and 3 replication. The treatments were categorised into three factors *viz.,* organic manures (FYM @ 2 kg/plant, vermicompost @ 1 kg/plant), inorganic fertilizers ($NPK_{25:10:10g/plant}$, $NPK_{37.5:15:15g/plant}$) and bio-fertilizers (VAM @ 100g/plant, PSB @ 100g/plant, Azospirillum @ 100g/plant) were given in an integrated manner. Among the organic manures (vermicompost) in inorganic fertilizers ($NPK_{37.5:15:15g/plant}$) and in bio-fertilizer (VAM) recorded highest plant height, collar diameter, crown diameter, basal area, number of branches over other treatments at eight months after treatment. In the interaction effect of organic manures (Vermicompost) x bio-fertilizer (VAM) and inorganic fertilizers ($NPK_{37.5:15:15\ g/plant}$) x bio-fertilizer (VAM) treatments showing significant effect at various months in growth parameters.

Among the given treatments soil pH varies within the range of 5.75 to 5.85; whereas electrical conductivity varies within 0.01 to 0.05 dsm^{-1} and organic carbon recorded in the range of 1.17 to 1.26 per cent. For the available nitrogen and potassium was recorded maximum in Vermicompost, $NPK_{37.5:15:15g/plant}$ and VAM. But for the available phosphorus, Vermicompost, $NPK_{37.5:15:15g/plant}$ and PSB recorded maximum. In the interaction effect, organic (Vermicompost) x inorganic fertilizer ($NPK_{37.5:15:15g/plant}$) recorded maximum available nitrogen (196.72 kg/ha), inorganic fertilizer ($NPK_{37.5:15:15g/plant}$) x bio-fertilizer (VAM) recorded maximum available potassium (166.97 kg/ha) and there was no significant effect shown in interaction effect of available phosphorus.