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Gmelina arborea as High Density Plantation to Reclaim the Red Lateritic Wasteland Lands of Chhattisgarh

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ABSTRACT

Gmelina arborea indigenous tree species to Indian sub continents is locally known as Khamar / Gambhar and is fairly grown in natural forest area and also cultivated as farm forestry. The study was carried out in high density plantation of *G. arborea* (1x1m) in marginal wastelands of Entisols at Dr Richhariya Research and Instructional Farm Baronda (Raipur). At 10.5 yrs growth of plantation, trees were felled and the accumulation of dry matter with N,P,K,C and combustible energy in root, bole, bark, branches, twigs and foliages. The survivorship of plantation was recorded 70 % upto 4^{th} years which was dropped to 56% at felling. The average height of plantation was 8.02 m with 10.4 cm collar diameter and 7.10 cm DBH. Total biomass of a tree was recorded16 kg (dry) which removed 22.5 g N, 6.18 g P and 504 g K with 8 kg carbon having 56,452.9 Kcal / tree combustible energy. Under storey herbage biomass observed at 4, 6 and 9 years of plantation age was found decreasing from 16.8 to 8.5 kg ha^{-1} also played important role in the changes of soil properties under plantation as compare to adjacent open field at 0-15, 15-30, 30-60 and 60-100 cm soil depth over 10.5 of plantation showed that acidity of soil was decreased, while increment was found in case of water holding capacity (21.4%), Organic carbon (96.3%), available Nitrogen (50.3%), Phosphorus (149.3%) and Potassium (64.6%). The coppice in fell tree was recorded 74 % with average of 6 shoots per tree. The study showed that resource utilization of marginal wasteland of red lateritic (Entisols), by high density plantation of *G. arborea* improved the soil quality at every soil depth along with the production of biomass of tree which can be used for timber and fuel wood.

Keywords:
coppicing, Gmelina, high density, production

INTRODUCTION

In the production process soil plays an important role where forest and agriculture crops are concerned with fertility status of the soil giving priority to take agricultural crops in high fertility soil and forestry crops in less fertile soil. Normally the *Entisols* are lacking of soil nutrients as compared to other soil (Pofali and Bhattacharjee 1970), hence a considerable proportion of such type of soil comes under wasteland which can be best utilized by forest crops and it can enhance some economic return from forest crops as well as it can also provide an environment to take some remunerative non-forest crops (Singh and Totey 1985).

Laterite soils in India are found in Eastern ghat of Orissa, Southern parts of Western ghat, Maharashtra and Andhra Pradesh, Tamil Nadu, Karnataka, Meghalaya, Jharkhand, Chhattisgarh and western part of West Bengal. It is red in colour due to presence of iron oxides and is coarse in texture with deficient in nitrogen, phosphorus and humus, but are rich in potash and lime hence not found suitable to agriculture, but plantation of MPTs in such soil is merely means to produce valuable biomass of commercial value, along with soil improvement process.

Biomass production is directly or indirectly related to the availability of plant nutrients besides the fast growth of the species and in high-density plantations there is more pressure on the soil nutrients. So, it is also necessary to study the relationship between soil nutrients and biomass production (Bhardwaj et al. 2001).

G. arborea is one of the fast growing indigenous multipurpose tree species, locally known as Khamar or white teak as it belongs to family Verbenaceae, which produce one of the best quality timbers in India. It is a strong light demander, though it can also stand in some shade during its early stages but it is very sensitive to water logging and weed competition (Douay1956), because of its high light demanding character, it regenerates naturally only in the open and on the edge of the forests with coppice shoots (Luna 1996).

MATERIALS AND METHODS

Chhattisgarh state has three distinguished agro-climatic zones *viz;* northern hilly region, central plains and southern Baster plateau. The high density plantation of *G. arborea* was raised in marginal wastelands denoted as Entisols at Dr Richhariya Research and Instructional Farm, Baronda (Raipur). Soil of Chhattisgarh plains varies from lateritic/ *Entisols* (20 per cent), Sandy loam/ *Inceptisols* (45 per cent), clay loam / *Alfisols* (10 per cent) and clayey / *Vertisols* (25 per cent). The soil depth varies from 20 cm in *Entisols* to 100 cm in *Vertisols*, with light undulation and general slopes of 2 per cent. A typical-semi-arid condition of soil appears just after the rainy season due to shallow soil and high rate of percolation.

The Entisols or red lateritic soil contain high percentage of gravels and sub soil layers are hard and compact, forming even lateritic pans with low pH (5.6 - 6.5), organic carbon (0.28 – 0.50 %), nitrogen (0.06%) and phosphorus with high potassium are the basic characteristics of Entisols and thus is responsible for causing moisture and thermal stress, which affect microbial activity and the availability of nutrients and subsequently unsuitable for economic cultivation of agriculture crops (Singh and Totey 1985).

Clear felling of plantation was done at age of 10.5 yrs and till then plantation was observed for survival parentage, growth of tree's height, CD and DBH yearly. Biomass of the plantation was recorded of sample trees having average height and DBH growth of whole plantations. Root of felled tree was excavated as per the standard methods (Ghosh and Chattopadyaya 1972 and Chandra et al. 1979). Analysis of nitrogen, phosphorus, potassium and combustible energy in different component of trees *i.e.* root, bole, bole bark, branch, twigs and leaves was done by standard analytical methods (AOAC 1975). After felling the tree coppicing behaviour of stumps was also studied. The dry matter production of herbage species in adjacent open and under the plantation area was observed by using 2x2m quadrates during 4,6 and 9th years of tree growth. Soil samples were collected at 0-15, 15-30, 30-60 and 60-100 cm depth under the tree and in adjacent open area. The composite samples were analyzed for WHC, pH, organic carbon, available nitrogen, phosphorus and potash as per the standard methods of Jackson (1973). All the data collected were analyzed for their standard deviation.

The climate of study site is dry sub-humid tropical with an average yearly rainfall of 1250 mm. Most of the rainfall (>80 per cent) is received during monsoon season from June to first fortnight of September and a few showers are expected during winters and occasionally during summer months. The average number of rainy days varies from 65 to 79. The mean monthly maximum temperature ranges from 27.3°C in December to 42.3°C in May. The mean minimum temperature varies from 13.2°C in December to 28.3°C in May. The maximum temperature goes beyond 45°C in May and minimum below 10°C in December. The relative humidity varies between 70-90 per cent from mid June to March end. Sunshine period in a day prolong more than 9 hours in summer and less than 7 hours in winter. Evaporation remains higher during April to June (10-13 mm day $^{-1}$) and low during July to February (2.4 to 5.0 mm day $^{-1}$).

RESULTS AND DISCUSSION

G. arborea plantation as high density (1x1m) was consistently observed for survivorship with its growth in height, collars diameter and diameter at breast height growth up to clear felling (Fig.1). Tree biomass along with C,N,P,K and combustible energy were observed at the time of tree harvesting (Fig. 2 to 10). The soil physical and chemical characteristics of soil were also recorded (Fig.11).

Survival percentage of high-density plantation of *G.arborea* was found to be affected during harsh day of summer when air temperature consistently remains higher during peak day period i.e. 40° to 45°C in month of May and June, therefore during summer, death of tree was occurred more than the rest of the months. Thus the overall survival of *G.arborea* was 82%, 70%, 64%, 58% and 56% at 2, 4, 6, 8 and 10 years of growth respectively. Naugraiya and Puri (1994 & 2001) observed that mortality of MPTS grown on Entisols in Chhatisgarh plains is caused by attack of termites followed by wind and illicit cut.

High density plantation of fast growing non leguminous timber trees species particularly in poor soil did not show impressive growth comparatively, where growth in height, collar diameter and diameter at breast height was 1.8m, 3.45cm and 123cm respectively after 2 years of plantation, and after 4 .years these were recorded 3.8m and 5.65cm with DBH of 2.8 cm (Fig.1). Tree growth rate was recorded 77.6 cm yr $^{-1}$, 1.1 cm yr $^{-1}$ and 0.72 cm yr $^{-1}$ for height, collar diameter and diameter at breast height. At the time of felling of tree these parameters were 8.54m, 11.18cm and 7.93cm respectively, while clear bole height was recorded 4.17m with 16.3 branches per tree.

Selected and representative tree stands were felled down and separated in to bole, bole bark, branches, twigs and foliage and weighed for their fresh weight. Root structure of these selected trees were excavated carefully and washed thoroughly. Cleaned air dry roots were weighed for fresh weight. Dry weight of each component was estimated with the help of their fresh and oven dry (75°C) samples.

The maximum dry matter accumulation was recorded in bole wood (9.92±4.86 kg tree $^{-1}$) while the bark accumulated 1.81±0.89 kg tree $^{-1}$. In high-density plantation of *G.arborea*, the formation of branches was not prominent thus produced only 0.99± 0.07 kg biomass tree $^{-1}$, which was less than the dry weight of bole bark (Fig.2). Dry matter in form of short branches or twigs was recorded lowest (0.23±0.16 kg tree $^{-1}$). Foliage is important components in tree as they help to synthesize the basic food of plant and also rich the soil organic component by decomposing, produced 0.41±0.16 kg dry matter tree $^{-1}$. Thus above ground dry matter of tree was 13.3± 0.64 kg tree $^{-1}$. Root of *G.arborea* was carefully excavated and gave 2.64±1.26 kg tree $^{-1}$ dry matter (Fig. 2). Dry matter distribution in different tree components was found in order of Bole (62%) > Root (16.5%) > Bark (11.3%) > Branches (6.2%) > Foliage (2.6%) > Twigs (1.4%) respectively (Fig.10).

The root system of *G. arborea* is comparatively shallow deeper, hence stored good dry matter in the tree. The production of dry matter and their distribution in different components was found to be varied under different set of management and climatic conditions for short rotation farm forestry in degraded land, which already was marked as poor land (IDRC, 1994). Naugraiya and Puri (1997, 2001), Naugraiya and Sisodia (2011) also revealed in their study of MPTs as short rotation management that in high density plantation for fuel wood purpose dry matter get shifted significantly in to main trunk of tree. In present study total biomass was also found to be accumulated maximum in bole and roots.

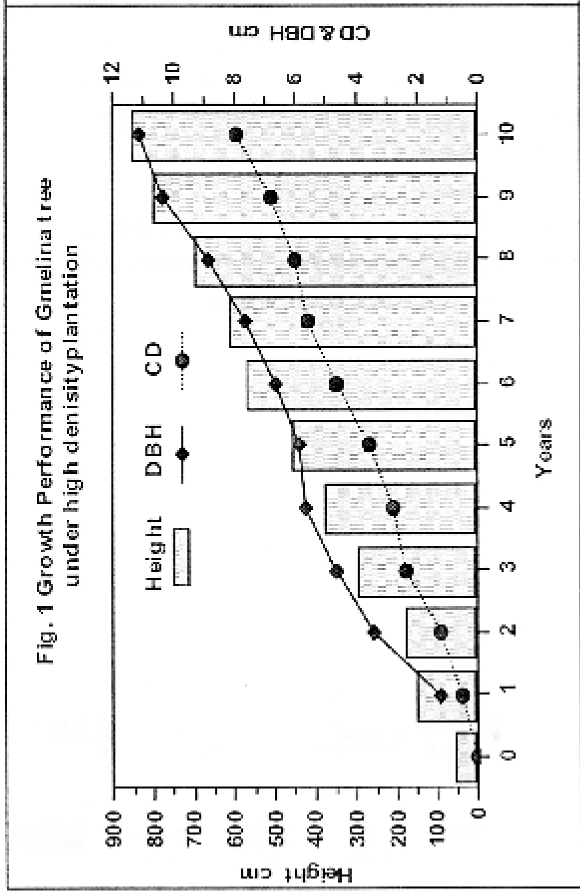


Fig. 1 Growth Performance of Gmelina tree under high denisity plantation

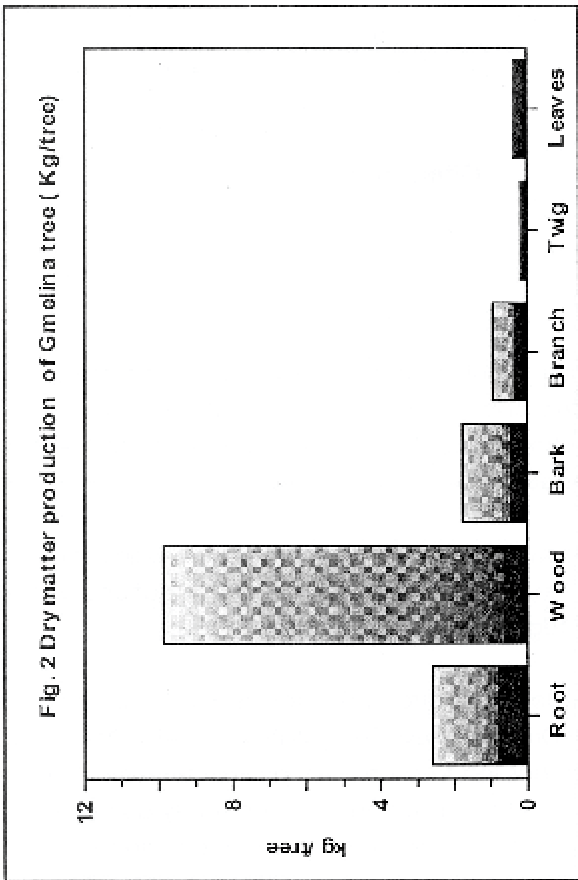


Fig. 2 Drymatter production of Gmelina tree (Kg/tree)

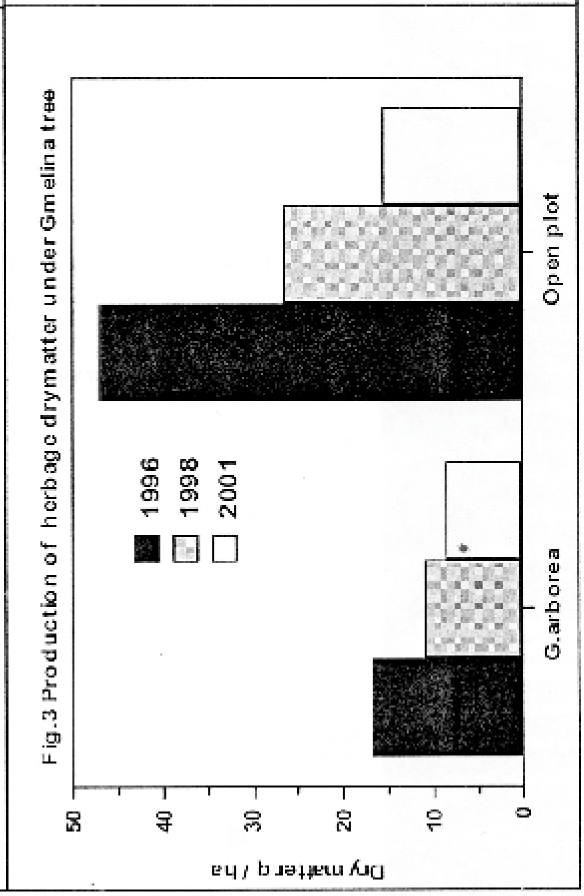


Fig.3 Production of herbage drymatter under Gmelina tree

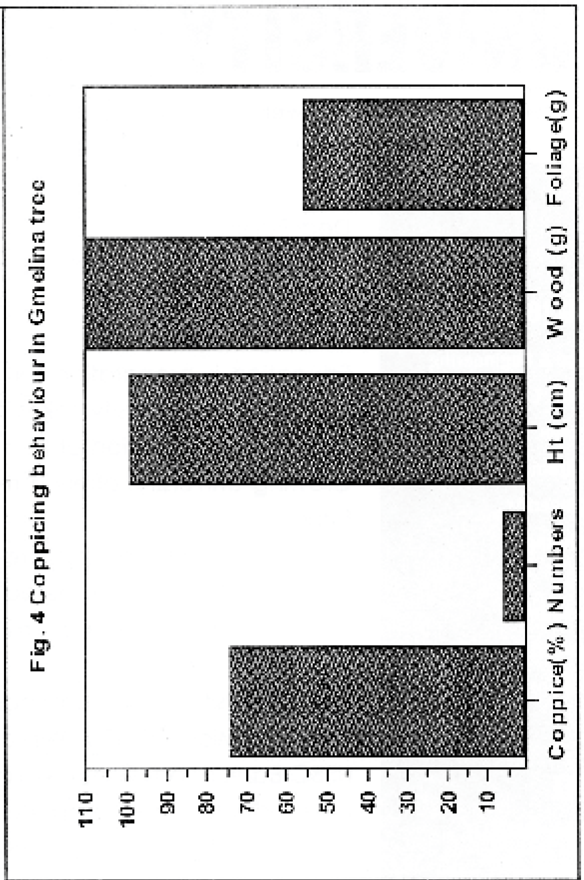


Fig. 4 Coppicing behaviour in Gmelina tree

Fig.5 Nitrogen in different parts of Gmelina tree

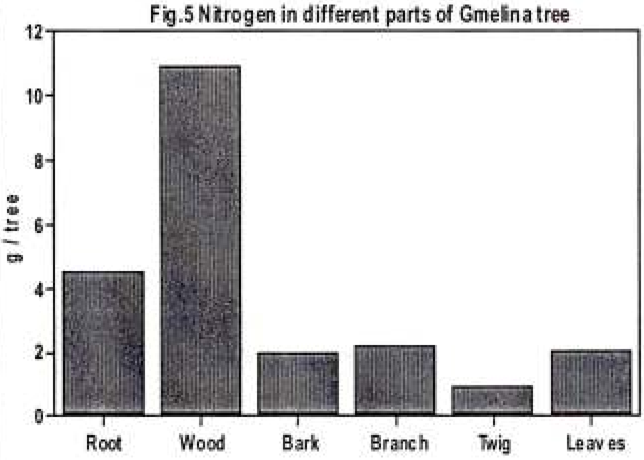


Fig.8 Carbon in different parts of Gmelina tree

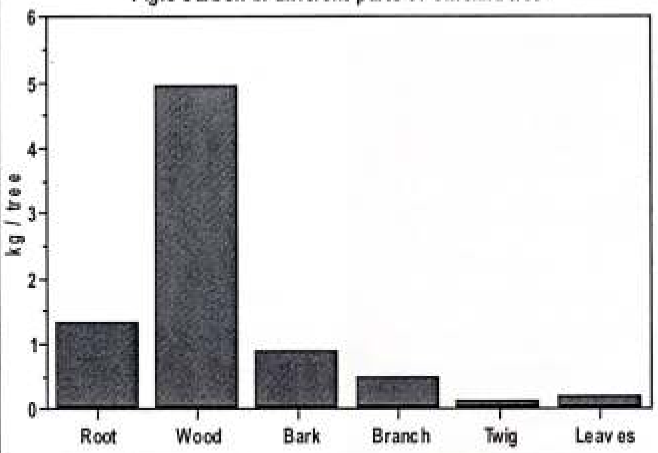


Fig.6 Phosphorus in different parts of Gmelina tree

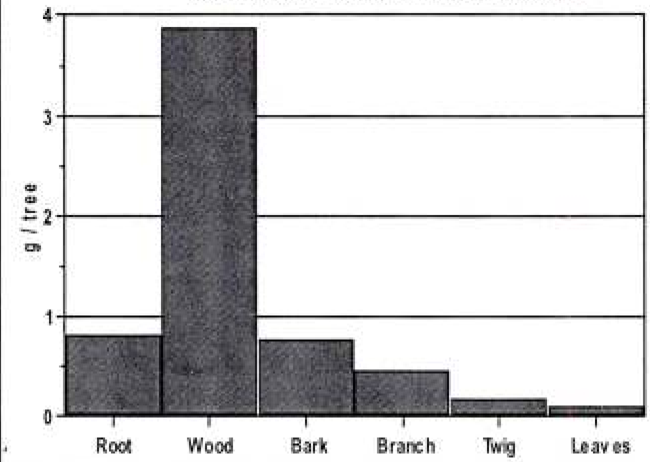


Fig.9 Combustible Energy restore in different parts of tree

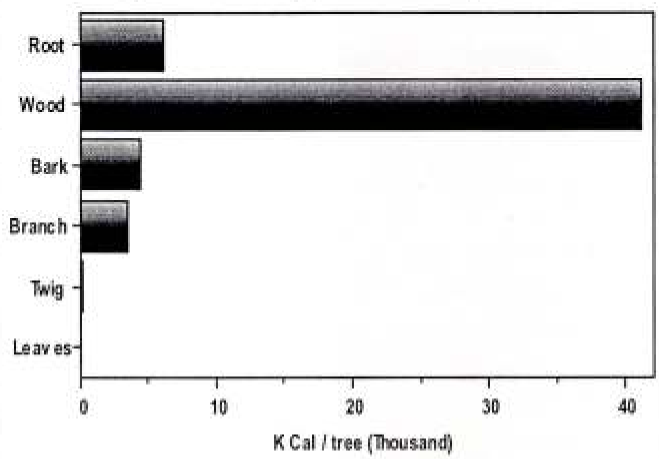


Fig.7 Potassium in different parts of Gmelina tree

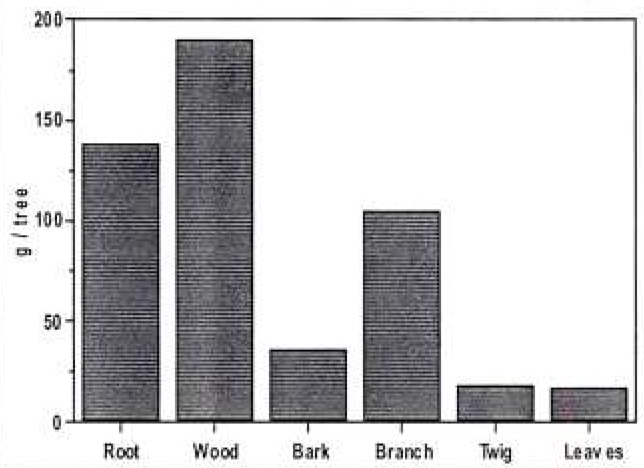
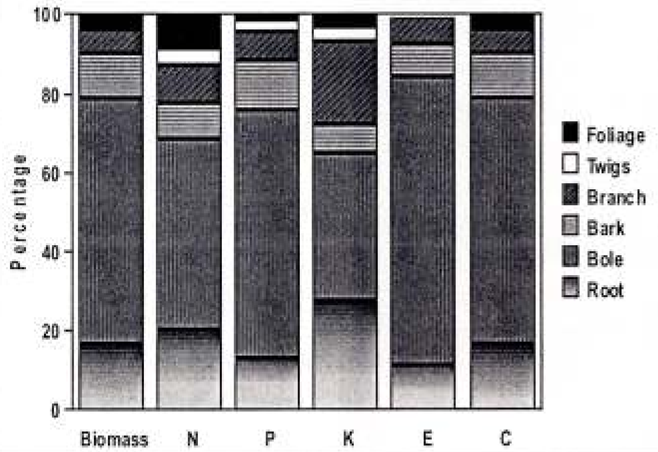


Fig.10 Distribution of Biomass, N,P,K, CE & C in Gmelina tree



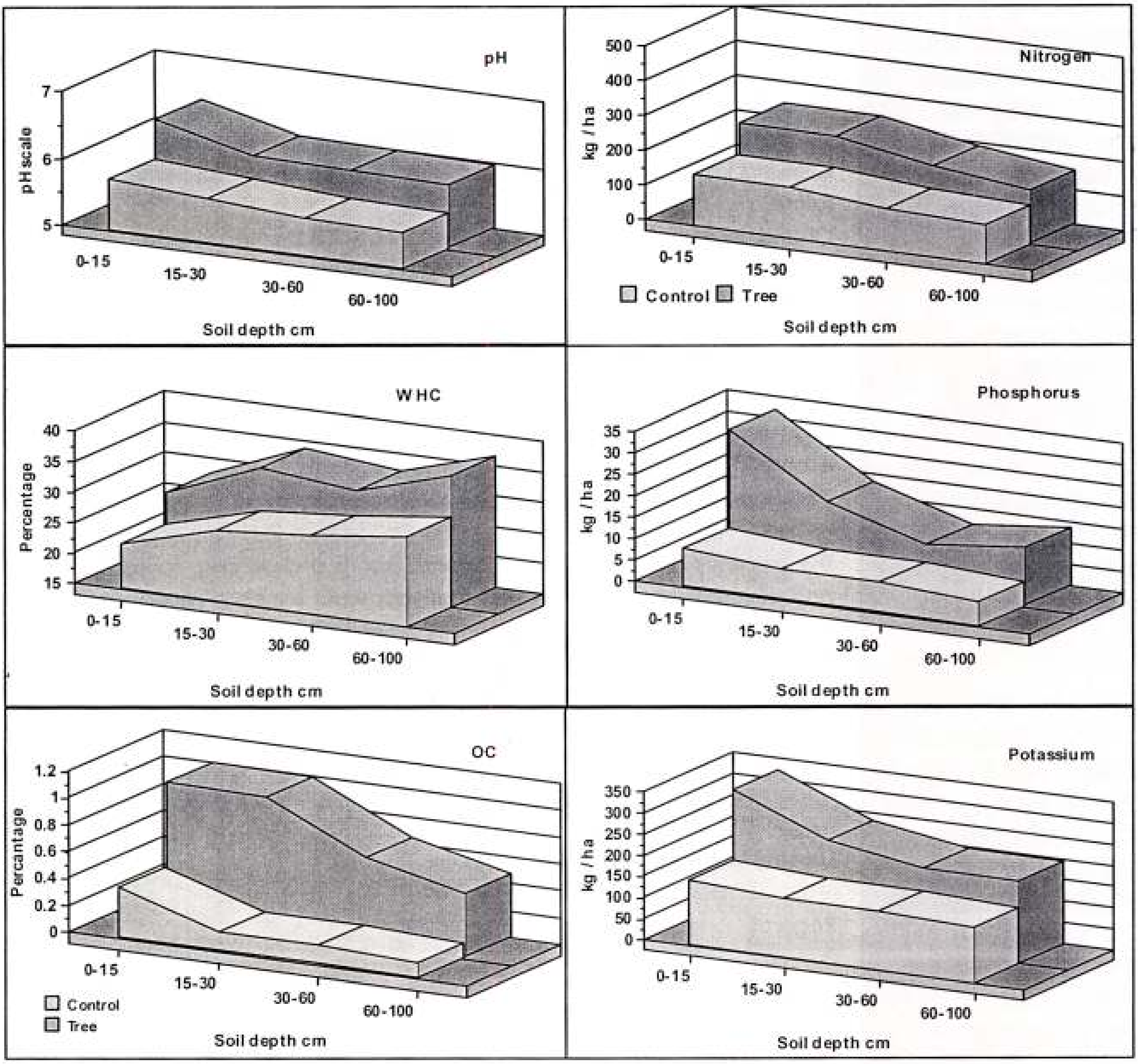


Fig.11- Effect of *Gmelina arborea* on soil properties after 10 yrs of growth

Local vegetation occupied the space and proliferates under plantation after competition get adjust according to micro climatic and neighbours. The biomass of such herbage species including grasses, legumes and forbs was recorded inside the plantation and adjacent open area (without tree) during 4^{th}, 6^{th} and 8^{th} years of growth and the results showed that herbage production was 47.2 q ha^{-1} in open area and 16.8 q ha^{-1} during early growth of trees *i.e.* 4^{th} yrs and gradually dropped by 43.8% and 67% at 6 and 9 year in open field while under *G.arborea* it dropped by 30.3% and 43.4% at 6 and 9 year of plantation respectively. Thus dry matter production of herbage species in both the situation was reduced however the structure of the herbage vegetation was quite different in both the situation (Fig. 3). Production of herbage species get influenced by the species composition when compare it between open and shade condition (Naugraiya and Pathak 2001 and Umrao et al. 2010). The species composition gradually get shifted to unpalatable, shallow, hardy unproductive perennial species and resulted to produce less biomass per unit area when it left over for a period.

Copping growth and production of above ground shoots after felling of trees was important part of plantation management if tree species had the potentialities of regenerating and flushing the new shoots. Survival percentage of stump for coppicing was 74% while average coppice shoot was recorded 5 per stump with average maximum height of 99.1cm after year one of growth with collar diameter of 1.09 cm. The two healthy shoots were left to grow, while rest was cut down with dry matter of 130.7 and 55.6 gm for woody stem and foliage respectively (Fig. 4). Coppicing behaviour of woody species is a genetical habit and generally influenced by edaphic and climatic features but it may also be influenced by the age of felled tree as well as cutting techniques leading to less injury to bole/stool tissues (Singh and Gupta 1990). Naugraiya et al. 2008 & Naugraiya and Sisodia (2011) also reported the similar coppice behaviour in *E.tereticornis* and *Leucaena leucocephala* when grown in Tamil Nadu and Chhattisgarh.

The removal of tree biomass from the growing area, C, N, P, K and other micro nutrients are also simultaneously removed. The carbon and major nutrients (NPK) removed in form of organic compound stored in different tree components with molecular energy which released on combustion (Fig. 5 to 8).

Total nitrogen phosphorus and potassium, accumulated in whole tree were 22.5±11.1 g N tree^{-1}, 6.18±3.09 g P tree^{-1} and 504.05 ±260.05g K tree^{-1} respectively with total carbon content of 8.0±6.4 kg tree^{-1}. The contribution of different parts of the tree for NPK accumulation showed that maximum nitrogen was shared by bole wood (48.51%) followed by root (19.92%), branch (9.69%), leaves (9.03%) and bole bark (8.85%) while minimum was shared by twig (4.0%). In case of phosphorus share of different tree component was found in order of bole (62.51%), root (13.25%), bole bark (12.28%), branch (7.43%), twigs (2.91%) and foliage (1.62%). The quantity of potassium was distributed in order of bole wood (37.57%), root (27.37%), branch (20.68%), bole bark (7.19%), twigs (3.74%) and leaves (3.35%).The sequestration of carbon in different tree components was accounted in order of Bole (62%) > Root (16.5%) > Bark (11.3%) > Branches (6.2%) > leaves (2.6%) > Twigs (1.4%) respectively (Fig.8 &10).

The accumulation of major nutrients (NPK) in different tree components showed that the bole was the storing maximum units in the tree followed by roots and than other woody components. The leaves possessed comparatively higher quantity of nitrogenous molecules, because of higher rate of physiological activities as photosynthesis and nitrogen assimilation etc than P and K. It is common phenomenon that concentration of nutrients in different parts of same species may be differed to a certain extent as per genetic potentialities and behaviour of plant species according to resources (Rodin and Bazilevidh 1967). Bhardwaj et al. (2001) and Naugraiya et al. (2004, 2008), Naugraiya & Sisodia (2011) also worked out the nutrient uptake in high-density plantation of *Populus deltoides*, *E. tereticornis*, *Leucaena leucocephala* and *Dalbergia sissoo* with more of less similar trend. Singh and Singh (1998) reported maximum nitrogen in foliage of MPTs when growth is red lateritic soil of Chhattisgarh.

The purpose of high-density plantation is to generate fuel wood for domestic energy (Fig.9). The combustion of different tree components in bomb calorimeter showed that the maximum energy was produced by bole wood (4165.9 k cal/ Kg) followed by branches (3732.3k cal / kg), bole bark (2563.6 k cal / kg), root (2375.1k cal / kg) and twigs (1658.8k cal / kg), while leaves produced minimum energy (358.2 k cal/kg). The total combustible energy extracted from tree on harvesting at 10 years of age was 56456.9 k cal / tree and it was accumulated in different part of tree in order of Bole wood > Root > Bole bark > Branches > Twigs > Leaves with share of 73.18,11.1, 8.23, 6.56, 0.68 and 0.26 % respectively (Fig.10). The generation of combustible energy in dry biomass is related to density / compactness as well as molecular structure of material.

Soil sample from open and under plantation area at 0-15, 15-30, 30-60 and 60-100 cm depth level were analyzed for Physical and chemical properties (Fig.11). Water holding capacity in open area was found maximum (29.8%) at 60-100 cm depth, and it decreased up to 22.4% with decreasing the soil depth. In plantation area water-holding capacity of soil was recorded more as compared to open field and the increment was 8.96% more at upper layer.

Level of pH was found slight acidic and it increased with increasing soil depth. The soil under *G. arborea* plantation was comparatively less acidic than open field and it ranged 5.96 to 6.34 and 5.77 to 5.55 from 0-15 to 60-100 cm soil depth in plantation and non-plantation area respectively. The level of organic carbon was recorded maximum at upper layer and minimum at deeper zone in both the cases. The level of organic carbon was found more or less 1.5 times higher in plantation field than open field.

Available nitrogen was estimated at upper layer of soil 235.2 kg N /ha in plantation area and 148.1 kg N /ha in open field. This decreased up to 156.8 kg N/ha in plantation area and 119 kg N/ha in open area at 60 to 100 cm soil depth. There was narrow difference between 0-15 and 15-30 and as well as 30-60 and 60-100 cm soil depth. Overall level of nitrogen found increasing under plantation area. Phosphorus in the form of P_2O_5 was recorded maximum at 0-15 cm depth (31.816 kg P_2O_5/ kg) and decreased up to 11.41 to 13.91 kg P_2O_5 /ha at upper and deeper layer of soil under plantation. Similar pattern was observed in open field but it was ranged 8.88 to 5.99 kg P_2O_5/ha from upper to deeper soil depth respectively.

Potassium is also important nutrient and play key role in mineral and water uptake. The level of potassium was high at upper layer (0-15cm) of soil and least at deeper layer (60-100 cm) and it ranged 213.8 to 106.92 kg/ha in open field. It was recorded 1.4 and 1.1 times higher at 0-15 and 15-30 cm depth respectively in plantation area as compare to open field but less at 30-60 and 60-100 out depth than open field. Similar results were observed by Banerjee and Nath (1991) in forest soil of Sikkim, Pal et al. (2013), Devi et al. (2013), Verma et al. (1998), Naugraiya and Dwivedi (2011) in Entisols for built up of NPK richness in the soil and

Above study reveals that utilization of red lateritic soil/ Entisols /Bhata lands lying as wasteland in 20 percent of total land area of Chhattisgarh state for short rotation farm forestry might be a land mark for producing the fuel wood, small timber and herbage biomass to not only meet out the demand of local communities but also help to keep environment healthy as carbon sequestration, soil water-water conservation as well as turning the soil into fertile land over a decade or so on.

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