

**TREE CROP INTERACTION STUDIES IN TEAK BASED  
AGROFORESTRY SYSTEM IN UPLAND PADDY AREA**

**A. MANJUNATHA**

**DEPARTMENT OF SILVICULTURE AND AGROFORESTRY  
UNIVERSITY OF AGRICULTURAL SCIENCES, DHARWAD  
COLLEGE OF FORESTRY  
SIRSI- 581401**

**JANUARY, 2003**

**TREE CROP INTERACTION STUDIES IN TEAK BASED  
AGROFORESTRY SYSTEM IN UPLAND PADDY AREA**

**Thesis submitted to the  
University of Agricultural Sciences,  
Dharwad in partial fulfillment of the  
requirements for the degree of**

**MASTER OF SCIENCE (FORESTRY)**

**IN**

**SILVICULTURE AND AGROFORESTRY**

**BY**

**A. MANJUNATHA**

**DEPARTMENT OF SILVICULTURE AND AGROFORESTRY  
UNIVERSITY OF AGRICULTURAL SCIENCES, DHARWAD  
COLLEGE OF FORESTRY  
SIRSI- 581401**

**JANUARY, 2003**

Released on 28 AUG 2003

U. A. S.  
University Library  
DHARWAD.

Acc. No. Th- 7018

# UNIVERSITY OF AGRICULTURE SCIENCES, DHARWAD

## CERTIFICATE

This is to certify that the thesis entitled "**Tree crop interaction studies in teak based agroforestry system in upland paddy area**" submitted by Mr. A. Manjunatha for the degree of **Master of Science (Forestry)** in **Silviculture and Agroforestry**, to the University of Agriculture Sciences, Dharwad is a record work carried out by him during the period of his study in this University, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

Sirsi

March



Dr. S. L. Madiwalar

Major Advisor  
Professor and Head  
Department of Agroforestry  
College of Forestry, Sirsi

Approved by

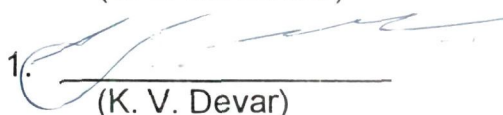
Major Advisor



(S. L. Madiwalar)

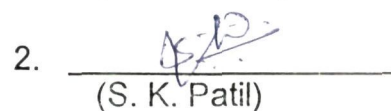
Members

1.



(K. V. Devar)

2.



(S. K. Patil)

3.



(K. Manjappa)

## ACKNOWLEDGMENT

It is with utmost respect and devotion, I place on record my profound sense of gratitude and indebtedness to **Dr. S. L. Madiwalar**, Professor (Agroforestry), Chairman of my advisory committee, College of Forestry, Sirsi. His close counsel, erudite guidance, unstinted support, critical evaluation, everlasting patience and constant encouragement made my task easy and has left indelible mark on this thesis work. A multitude of problems was solved through his guidance in the very right direction at the right time. I consider it as a privilege to work under his guidance. I owe a great deal to him and remain deeply indebted to him.

I avail this privilege to express my sincere gratitude and thanks to **Dr. K. V. Devar**, Professor and Head (Silviculture), **Dr. S. K. Patil**, Director of Instruction (Forestry) and **Dr. K. Manjappa**, Assistant Professor (Agronomy), who acted in members of advisory committee, for their immense support and valuable suggestion throughout this study.

I express my deep sense of gratitude to **Sir. G. V. Naik**, Farm Superintendent, ARS, Mundgod and **Sri. Shivaprasad** for providing the necessary facilities during the field experiment.

I sincerely acknowledge the help rendered by **Sri. Krishna. A.**, **Sri. Dasar, G. V.**, **Sri. Chennkeshava**, **Sri. Marigoudra, R. M.**, **Sri. Ramesh Rathod** and **Sri. Maheshwarappa**. who helped me in various ways during the course of this work.

I sincerely acknowledge the help and constant support of my **classmates** and **friends**, College of Forestry, Sirsi, during my field observation who made this endeavor possible.

I shall be failing in my duty if I forget to place on record the facilities offered *alma mater*; **College of Forestry**, Sirsi. The uninhibited and timely help by the **office** and **library staff**, College of Forestry, Sirsi is warmly acknowledged.

I remember with great respects my **parents** and **brothers** for their blessings, affection, words of encouragement, I would not have accomplished this work without their support. To express my sincere gratitude to them in few words is rather restrictive in expression of depth.

SIRSI

MARCH, 2003

  
(A. MANJUNATHA)

## CONTENTS

| Sl. No. | Title                | Page No. |
|---------|----------------------|----------|
| I.      | INTRODUCTION         | 1        |
| II.     | REVIEW OF LITERATURE | 4        |
| III.    | MATERIAL AND METHODS | 22       |
| IV.     | EXPERIMENTAL RESULTS | 35       |
| V.      | DISCUSSION           | 74       |
| VI.     | SUMMARY              | 86       |
| VII.    | REFERENCES           | 93       |

## LIST OF TABLES

| Sl. No. | Title                                                                                                                                  | Page No. |
|---------|----------------------------------------------------------------------------------------------------------------------------------------|----------|
| 1       | Rainfall and temperature data for the period from April 2001 to March 2002 and mean for last 16 years (1985 – 2000) at ARS, Mundgod.   | 23       |
| 2       | Physical and chemical properties of the soil of the experiment site.                                                                   | 24       |
| 3       | Details of spacing and cultural operations                                                                                             | 24       |
| 4       | Plant height (cm) of teak at different stages of growth as influenced by fertilizer levels                                             | 36       |
| 5       | Collar diameter (cm) of teak at different stages of growth as influenced by fertilizer levels                                          | 38       |
| 6       | Number of stem nodes per plant at different stages of growth as influenced by fertilizer levels                                        | 39       |
| 7       | Number of leaves per plant at different stages of growth as influenced by fertilizer levels                                            | 41       |
| 8       | Leaf area (cm <sup>2</sup> ) per plant at different stages of growth as influenced by fertilizer levels                                | 43       |
| 9       | Crown diameter (cm) per plant at different stages of growth as influenced by fertilizer levels                                         | 45       |
| 10      | Crown spread (cm <sup>2</sup> ) per plant at different stages of growth as influenced by fertilizer levels                             | 46       |
| 11      | Internodal length (cm) and volume of stem (cm <sup>3</sup> ) per as influenced by fertilizer levels                                    | 48       |
| 12      | Dry matter production (g/plant) and its distribution in different parts at 20 MAP as influenced by fertilizer levels                   | 49       |
| 13      | Net increment in plant height (cm), collar diameter (cm) and number of stem nodes per over 8 months as influenced by fertilizer levels | 51       |

Contd...

|    |                                                                                                                                                               |    |
|----|---------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| 14 | Form factor and fertilizer use efficiency (FUE) of teak plants as influenced by fertilizer levels                                                             | 53 |
| 15 | Uptake of N, P and K by teak (g/plant) a influenced by fertilizer levels                                                                                      | 55 |
| 16 | Plant height of paddy (cm) at different growth stages as influenced by distance from teak row and fertilizer levels imposed on associated teak                | 57 |
| 17 | Dry weight per plant (g) at different growth stages as influenced by distance from teak row and fertilizer levels imposed on associated teak                  | 59 |
| 18 | Number of tillers per meter length of row at different growth stages as influenced by distance from teak row and fertilizer levels imposed on associated teak | 61 |
| 19 | Panicle length (cm) and thousand grain weight of paddy as influenced by distance from teak row and fertilizer levels imposed on associated teak               | 63 |
| 20 | Grain yield (kg/ha) and straw yield (kg/ha) of paddy as influenced by distance from teak row and fertilizer levels imposed on associated teak                 | 65 |
| 21 | Relative crop yield of paddy (%) as influenced by distance from teak row and fertilizer levels imposed on associated teak                                     | 67 |
| 22 | Uptake of nutrients (N, P and K) by paddy as influenced by distance from teak row and fertilizer levels imposed on associated teak                            | 69 |
| 23 | Soil moisture content (%) as influenced by distance from teak row and fertilizer levels imposed on associated teak                                            | 71 |
| 24 | Average growth attributes of sole teak (with no paddy) and teak associated with paddy at different stages of growth                                           | 72 |

---

## LIST OF FIGURES

| Sl. No. | Title                                                                                                                                                | Between<br>page |
|---------|------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| 1       | Rainfall data for the period from April 2001 to March 2002 and mean for last 16 years (1985 - 2001)                                                  | 23–24           |
| 2       | Mean monthly maximum and minimum temperature of 2001-2002 recorded at ARS, Prabunagar                                                                | 23–24           |
| 3       | Plan of layout of experiment                                                                                                                         | 26–27           |
| 4       | Plant height of teak at different stages of growth as influenced by fertilizer levels                                                                | 36–37           |
| 5       | Collar diameter (cm) of teak at different stages of growth as influenced by fertilizer levels                                                        | 36–37           |
| 6       | Number of stem nodes per plant at different stages of growth as influenced by fertilizer levels                                                      | 41–42           |
| 7       | Number of leaves per plant of teak at different stages of growth as influenced by fertilizer levels                                                  | 41–42           |
| 8       | leaf area per plant at different stages of growth as influenced by fertilizer levels                                                                 | 43–44           |
| 9       | Crown diameter (cm) per plant at different stages of growth as influenced by fertilizer levels                                                       | 43–44           |
| 10      | Volume (cm <sup>3</sup> ) of stem per teak plant as influenced by fertilizer levels                                                                  | 49–50           |
| 11      | Total dry matter production by teak (g/plant) as influenced by fertilizer levels                                                                     | 49–50           |
| 12      | Grain and straw yield (kg/ha) of paddy as influenced by distance from teak row and fertilizer levels imposed on teak                                 | 65–66           |
| 13      | Soil moisture content (%) by growth of associated teak plants treated with various fertilizer levels and its interaction from distance from teak row | 71–72           |

## LIST OF PLATES

| Sl. No | Title                                                                                      | Between page |
|--------|--------------------------------------------------------------------------------------------|--------------|
| 1      | Plate showing teak plants planted on terrace bunds                                         | 26– 27       |
| 2      | Plate showing paddy crop in association with bund planted teak plants in the near vicinity | 26– 27       |
| 3      | Plate showing teak plants on terrace bunds with no teak paddy crop in the near vicinity    | 26– 27       |
| 4      | Plate showing weeding and soil working in teak plants after harvest of adjacent paddy crop | 26– 27       |

## INTRODUCTION

## Introduction

With the rapid population growth and consequent rising demands for fuel wood and timber, pressure on the natural forests is increasing. This in turn shortens the fallow periods of traditional farming systems and decimates forest covers. The impact of degradation of forest are in the form of soil erosion, degradation of watersheds, loss of biological diversity, climatic changes and reduction in the economic contribution of forest to human life.

India has moved into a new millennium with additional burden of wood and fodder. The demand for the industrial wood and timber is around 47 million. m<sup>3</sup> against the actual production of 14 million. m<sup>3</sup> (Shaikh, 2000). Under these circumstances agroforestry is one such option for an expansion of tree cover in the areas outside conventional forests. Farmers and land owners in different parts of the country integrate a variety of woody perennials in their crop and livestock production fields depending upon the agroclimatic conditions and local needs. Most of these practices, however, are very location specific and information on these is very scanty.

Prime among the Indian timber yielding tree species is teak (*Tectona grandis*). Among housing and furniture grade timbers in India, teak wood constitutes the premier class. India has over 9.27 m ha under natural teak forest (Bapat and Paulari, 1998), but severe restriction on the harvesting of teak from natural forests, in the recent past, have limited the domestic supply. Even though India is one of the largest producer of teak in the world, a large amount of timber is imported to meet the demands of plywood and venire

industries (Bebarta, 1999). Hence, teak plantations have become important to fill the gap between demand and supply.

Teak is preferred as an agroforestry species due to its high timber value, ready market and assured returns. In addition, it has useful features like deciduous nature, straight and cylindrical bole, sparse canopy and deep root system, which are desired characteristics for agroforestry. This tree can be integrated into agricultural system, which is capable of meeting challenges of timber requirement.

In Karnataka, hill zone (Zone-9) represents a unique agroclimatic situation with a wide variety of ecological conditions. It contains 13.4 per cent of the geographical area of the state. Upland paddy cultivation is a dominant land use system in hill zone. The productivity of this system is declining in the recent past. Introduction of perennial component in the existing system is one of the options to improve the productivity. Teak could be a potential species to introduce in upland paddy area due to its varied advantages. The climatic conditions in the hill zone are also quite congenial for the growth of teak. There is ample scope to introduce teak on terraced bunds of upland paddy area, which is presently being not utilized optimally.

Fast growth of the teak in the initial stages is critical for its better establishment as it often faces the threat of weed competition in initial stage. Ensuring availability of adequate nutrients in soil is a crucial factor to encourage faster growth. Initial vigour achieved in growth helps to smother competing vegetation which in turn results in better establishment and survival (Ananthapadmanaba, *et al.*, 1998). Application of fertilizers in excess of required quantity not only increases production but also may have

detrimental effect on plant and soil. Therefore, finding optimum quantity of fertilizer is of great importance. Generally, tree species in agroforestry compete with associated crops for available resources. This effect may vary with species, age and associated crop. The quantification of effect of tree specie on associated crop is equally important to work out the economic feasibility of the system.

Although nutrient requirement of teak for its first year growth and its impact on adjoining paddy crop have been studied (Marigoudra, 2001), such information for subsequent years is not available. Since nutrient requirement and competitive effects vary with advancement in age, generating information in these aspects is of great significance. With this point in view, the present study was made with the following objectives.

1. To study the response of one year old teak grown on terrace bunds of upland paddy to various fertilizer levels.
2. To assess the competitive effect of one year old teak on the growth and yield of associated paddy crop.
3. To study the effect of upland paddy crop on the growth of associated teak.

## REVIEW OF LITERATURE

## **II REVIEW OF LITERATURE**

The literature on the effect of manure and fertilizer application on growth attributes of teak and other tree species, nutrient uptake and tree crop interaction for various resources are reviewed in this chapter.

### **2.1 Effect of manure and fertilizers**

Although, teak is believed to be slow growing but now a days as a result of improved and sound management practices, it is being treated as a short rotation crop under farm forestry. The relevant literature regarding the influence of manure and fertilizers on growth and productivity of teak and some other tree species are reviewed in this section.

#### **2.1.1 Composition of farm yard manure (FYM)**

Farm yard manure constitutes a dependable source of essential nutrients besides improving soil physical conditions. Application of organic manure in general, improves the availability of micronutrients like zinc, iron, manganese and copper.

The Farm yard manure is produced mainly with animal excreta. It consists of a mixture of cow dung, the liquid excreta or urine, the bedding materials used for cattle and remnants of straw and plant stalks fed to cattle. The nutrient content of FYM varies with the constituents or composition of FYM.

In a study by Chatterjee *et al.* (1979), the nutrient content of FYM was 0.64 per cent N, 0.07 per cent P and 0.29 per cent K. Sharma and Mitra (1989) reported that the FYM contained 26.1 per cent of C, 1.71 per cent of P and 2.04 per cent of K on dry weight basis, the C: N ratio was

15:1. FYM used in the trials conducted by Sriramchandrasekaran *et al.* (1996) had 1.2 per cent of N, 0.2 per cent of P, 1.96 per cent of K and 26.9 per cent of C with C: N ratio of 22:40. On an average, FYM contains 0.5 per cent of N, 0.2 per cent of K<sub>2</sub>O (Balasubramaniyan and Palaniappan, 2001).

### **2.1.2 Effect of FYM on soil properties, plant growth and nutrient uptake**

FYM coupled with inorganic fertilization had a beneficial effect on available N content. When optimum quantity of FYM was combined with recommended levels of NPK, it was found to enhance the soil fertility in terms of available N (Marthan *et al.*, 1978).

Application of organic manure with or without mineral fertilizers increased the capacity of a black soil to retain more cations. Continuous application of FYM increased the CEC and exchangeable cations (Hesse, 1984). Addition of FYM along with NPK fertilizer increased the available K status of the soil (Aravind, 1987).

Singh and Srivastava (1988) reported that net balance of soil available N, P and K increased with FYM or green manure applied either alone or in combination with inorganic fertilizers. Meena Nair and Peter (1990) revealed that application of high rates of FYM (15 t/ha) and inorganic fertilizers (175:40:75 NPK kg per ha) increased mango fruit yield during all the three seasons as compared to organic fertilizers or inorganic fertilizers alone. Kumar *et al.* (1992) indicated that FYM did not affect bulk density of soil but increased the water stable aggregates (>2mm).

Roe *et al.* (1993) found that application of compost increased the concentration of P, K, Ca and Mg content in leaves of vegetable crops and decreased the copper concentration, while leaf N concentration increased with an increase in fertilizer rates.

Combined application of organic, inorganic and bio fertilizer viz., FYM 2.5 kg + DAP 50 gram + Azospirillum 50 g + Phosphobacteria 50 g per tree registered the neem plant height (437.9 cm) and more girth (at bottom, 50 and 100 cm) at three and half years (Thirumurugan and Govindan, 2001). Farm yard manure application showed four fold increase in plant height and survival in *Prosopis cineraria* (Gupta and Sharma, 2001).

### **2.1.3 Effect of fertilizers on growth attributes of teak**

Being an essential constituent of amino acid, nitrogen is required in protein synthesis. Considering the role in plant functions and its reactivity in the biosphere, it is not surprising that this element is the most universally deficient for optimum crop yields (Donald *et al.*, 1963).

Phosphorus occur in plant in much smaller quantity than N and K. The two most important functions of phosphorus in plants are its involvement in the transfer of energy with in the plant and its structural role in number of compounds. The reaction of phosphorus with organic substances in the plant to form energy rich compound is one of the most important reaction in plant metabolism. The high energy phosphate of such compounds could be transferred to other compounds such as glucose. It shown as essential for photosynthesis, inter-conversion of carbohydrates and related compounds.

It is noteworthy that excessive P fertilization may not prove meaningful particularly for long term effects in tree growth, which is supported well by the large, deep and extensive root system (Sahu and Manhot, 1988).

White and Cameron (1967) registered better growth of teak plants when planted with 450 kg per hectare of NPK compound fertilizer. Application of calcium and potassium is ideal as shortage of these two are likely to occur in young plantation (Hase *et al.*, 1980).

Application of N and P significantly increased height and dbh in ten and twenty year old plantations and volume production in the 10 year old teak plantation (Ram Prasad *et al.*, 1986). Prasad *et al.* (1986) inferred that application of 300 kg N and 150 kg  $P_2O_5$  per hectare annually for five years increased height and diameter of teak significantly. Kushalappa (1987) reported that teak plantation growth was better with application of 2 kg lime and one kg mussoire rock phosphate per plant.

Nanda Kishore (1987) reported that diammonium phosphate significantly increased height of teak plantation in the first two years. He recommended a dose of 40 g DAP per teak plant in two splits during initial two years. Rangaswamy *et al.*, 1991 observed increased growth of teak seedlings with the application of NPK fertilizer. Application of 200 kg of N, 100 kg of  $P_2O_5$  and 100 kg  $K_2O$  per hectare to five month old seedlings significantly increased root length, shoot length and collar diameter (Soukar and Kumbhare, 1991). Torres *et al.* (1993) reported that 2 year old teak plantation showed a significant response (in both diameter and height growth) to 740 kg per ha fertilizer dose and effect on older plantation was not noticed.

Application of urea at 200 and 300 g per plant resulted in taller plants of teak, where height recorded at 30 months were 4.35 and 4.48 m respectively (Bheemaiah *et al.*, 1997).

Mutanal *et al.* (1999) observed higher increment in height, dbh, basal area and crown spread of teak with the application of 300:50:300 kg NPK per hectare compare to 100:50:100 kg NPK per hectare. Volume and biomass production was also higher with higher levels of fertilizer.

Marigoudra (2001) found that application of 2.5 kg FYM + 30:15:30 g NPK per plant during first year of planting of teak showed significantly higher height, collar diameter, number of leaves and crown spread compare to control and other levels of fertilizer.

#### **2.1.4 Effect of fertilizers on growth attributes of other trees**

Dutta and Panthanian (1986) working with fertilizer effects on the growth of *Luecaena* under Indian conditions reported that use of phosphoric fertilizer was more beneficial than using N P fertilizer, thus indicating greater role of phosphorus in the nutrition of leguminous tree species.

Hunter and Grahm (1987) conducted trial with *Pinus radiata* in Auckland (Newzealand) in which superphosphate was applied at 650 – 2500 kg per ha once or various time intervals. The results showed that large increase in height and basal area growth were obtained with 650 kg per ha applied at trial establishment and/or 5 to 10 years after establishment. But heavier application produced very little additional response.

The effect of fertilizer on 2 year old pine seedlings showed better basal area growth. The response was increased with increasing nitrogen doses (Shepard and Lemin, 1989).

Application of 50 g of superphosphate and 25 g of urea per plant for 3 year old *Peltophorum pterocarpum*, *Eucalyptus camaldulensis* and *Acacia nilotica* enhanced the survival rate by 67, 65 and 57 per cent, respectively (Gupta, 1991). Gupta *et al.* (1993) reported that the combination of N and P produced more than four times the number of leaves per plant over control (with no fertilizer) in *Pithecellobium dulce*.

Gupta *et al.* (1994) reported that nitrogen application at the rate of 9 g per plant improved the plant height of *Ailanthus excelsa* by 24 per cent one year after planting, while phosphorus application at the rate of 6 g  $P_2O_5$  per plant improved the root length by 27 per cent and root spread by 5 per cent. Phosphorus application showed better response in the second year, while pre-planting application of 9 g nitrogen combined with 6 g  $P_2O_5$  per plant was the best treatment improving the height of two year old trees from 144 to 213 cm. Singh and Banerjee (1994) reported increased biomass production of *Albizzia procera* when fertilized at the rate of 150:50:150 NPK kg per hectare.

Grewal *et al.* (1995) studied the effect of nitrogen (25 g/plant) on nursery raised *Eucalyptus* seedlings planted at 1x1 m spacing in 60 cm deep auger holes. He found that the application of phosphate was superior in terms of growth, biomass production and monetary return from *Eucalyptus* harvested after 42 months of planting.

Application of nitrogen showed an increased growth, diameter and dry matter accumulation in *Albizzia procera* seedlings. Urea as nitrogen source resulted in better growth than other nitrogen sources applied in nutrient solution (Ashish Mishra and Yogesh Mishra, 1999).

Banerjee *et al.* (1999) reported that application of N and P to *Dalbergia sissoo* produced three times more root biomass, 5 times more stem biomass 3 times leaf biomass and 4 times total biomass over control (with no N and P).

Addition of nitrogen fertilizer at a rate 132 g per plant for *Acacia saligna* promoted growth during first year, while 60 g per plant was enough to ensure survival through the second year. Initial application of 60 g P<sub>2</sub>O<sub>5</sub> per plant was optimum for both horizontal and vertical growth (Abou deya, 1999).

#### 2.1.5 Nutrient uptake

Nitrogen concentration in teak leaf as well as in shoot and root increased steadily with the increase in N levels (Deol and Khosla, 1983). They also observed increase in foliar N content with N fertilization in *Populus ciliata* and *Eucalyptus tereticornis*.

The N and K content in leaves as well as in root and shoot decreased with increasing levels of P in *Eucalyptus grandis* (Prasad *et al.*, 1984), *Celtis australis* and *Acacia mollissima* (Rao and Rama Mohan, 1990). The inverse relationship between P application, N and K content in plant parts of *Eucalyptus* was attributed to the antagonistic effect of N at higher doses.

Application of inorganic fertilizers causes major changes in the soil chemistry, which in turn influences the availability and cycling of nutrients (Arden-Clarke and Hodges, 1988). Teak trees supplied with adequate phosphorus (300 to 320 kg/ha) had higher P uptake, which was evidenced by higher foliar phosphorus content (Glaser and Dreschel, 1992). They also

found positive correlation between foliar P content and topsoil phosphorus content.

Swaminathan (1995) revealed that increased foliar nutrient content in teak was evident in fertilized plots compared to control which was attributed to the exogenous addition of fertilizers. Ananthapadmanabha *et al.* (1998) reported that application of inorganic fertilizers in the form of calcium nitrate and di-ammonium phosphate (upto 100g/plant) increased the concentration of N, P and K in teak leaves (3.86, 0.34 and 0.86%, respectively) compared to that of control (2.5, 0.2 and 0.85%, respectively).

Koul *et al.* (1995) reported that higher uptake of N and K at P level of 40 kg per hectare was attributed to the relatively higher biomass production in *Bauhinia variegata* seedlings.

## **2.2 Tree – crop interaction**

The components of plant species in agroforestry system depend on the same growth resources such as light, water and nutrient and hence there will be influence of one component of a system on the performance of the other component as well as on the whole system. These are referred as tree crop interactions. These interactions may be positive (complementary) or negative (competitive). The balance between these positive and negative effect determines the overall effect of the interaction in a given agroforestry combinations. Hence, the knowledge of these interactions is helpful in proper management of agroforestry system for sustained production of multiple outputs.

### **2.2.1 Resource sharing in agroforestry**

A mixture of herbaceous crop and tree in an agroforestry system share resources (moisture, nutrients, light and space) with each other. The resource sharing could be below ground and/or above ground. Nature of competition and chemical interference (allelopathy) depends on tree species, its age, its spread, direction of planting and agricultural crops and nature and availability of growth resources. There could be positive and/or negative interactions among trees and crops. Resource sharing for moisture and nutrients are relatively more important in agroforestry system. Lateral spread of roots and concentration of fine roots in soil upto 50cm depth pose competition for nutrients with other crops.

Soil moisture is often the major factor limiting the yield of tree and crop more under rainfed condition. Soil moisture competition between trees and crops is often cited as primary factor causing observed reduction in crop yields in alley cropping studies. In agrisilviculture systems, presence of a well developed tree canopy and resultant shade make the light as an important factor in determining the potential of understorey crops when moisture is not limiting.

### **2.2.2 Interaction for above ground resource**

The yield of the crops, whether trees or agriculture crops are dependent on the radiation energy, which they intercept. The relation between dry matter yield and intercepted energy is approximately linear and the fraction of the photosynthetically active radiation, which is intercepted by a crop, sets the upper limits to its potential productivity under those climatic conditions.

Above ground resource sharing (light and space) depends upon the age, species, density and spatial arrangement of trees. The amount of light intercepted by tree depends on the amount of incident light and fraction of light intercepted canopy.

In general, availability of the light is the most important limiting factor in situation with relatively fertile soils and adequate water availability. The relative importance of the light decreases in moisture stress condition as well as on site with low fertility soils (Cannel, 1983).

Balasubramaniyan (1983) attributed the reduction in yam yield in alley cropping to shade from *Leucaena* hedgerows that were managed as live stake for yam. In the irrigated fields of North India, the shades of the *Eucalyptus tereticornis* and mango grown on the bunds reduced the rice yields to the extent of 25 and 55 per cent, respectively. Higher reduction in yield under mango was attributed to the dense canopy nature of mango (Srivastava *et al.*, 1983).

The study of the microclimate variation around the tree cover by Harsh and Tewari (1988) revealed that in silvi-pastrol system with *Acacia tortilis*, only 14 to 30 per cent of total incident light was received around trees and was insufficient for the growth of grass. At Dharwad, highest light transmission ratio (LTR) was observed in teak followed by *Eucalyptus*, *Leucaena* and *Casuarina* (Chandrashekariah, 1986 and Bhat, 1988).

Nadagoud (1990) also observed maximum LTR in teak and minimum in sissoo and *Acacia auriculiformis* and LTR was lowest near tree line and increased gradually with increasing distance from the tree line. The reduction in LTR was 8, 33, 48 and 51 per cent under anjan, eucalyptus, neem and

sissoo, respectively (Korwar, 1992). Radiation varied from 15-30 percent around *Acacia nilotica* trunk which interfered with the sorghum for light utilization in arid zone (CAZRI, 1992).

Maize yield decreased almost proportionately upto 50 per cent with reduction in radiation (ICRAF, 1993). Wheat grain yield decreased with increasing duration of shading (Nazir *et al.*, 1995). Crown shading of *Paulownia* had affected wheat grain yield and 100-grain weight with closer distance from the tree as compared to control (Lang *et al.*, 1995). Maheta *et al.* (1996) recorded maximum light intensity under open field and minimum with *Casuarina*.

In *Hardwickia binata* based agroforestry system under semi arid conditions, sorghum was least affected compared to pearl millet, pigeon pea, soybean and cotton due to the shade of the trees (Khadse and Bharad, 1996). Similarly, lower yield reduction of chickpea and field bean under *Casuarina* compared to *Adina cordifolia* and *Gmelina arborea* was attributed to interception of more light by *Casuarina* trees (Maheta *et al.*, 1996).

Studies on light interception in six year jack fruit, mango and tamarind based agroforestry systems showed that the trees reduced the availability of light to finger millet crop due to interception of light by them. Jack intercepted more light compared to tamarind and mango due to its wider and denser canopy. During the noon hours (12.00- 13.00 hr) of the day, jack intercepted light up to 4 m from the tree, while mango and tamarind intercepted up to 2m from the tree. Closer spacing of 8 x 8 m greatly reduced the availability of light to finger millet due to higher light interception by trees compared to wider spacing to 12 x 12 m and 16 x 8 m (Basavaraju, 1997).

Thus, it is evident that trees compete for light with the crops in agroforestry systems. Trees with dense canopy compete more for light than trees with sparse canopy. The competition for light increases with the age and density of trees. The crops vary in their tolerance to shade. Planting of trees in east – west direction reduce the competition for light to some extent.

### 2.2.3 Interactions for below ground resources

The degree of availability of moisture and nutrients depends on the tree and crop species, their density and age of trees. In alley cropping trial of *Leucaena leucocephala* with cowpea, castor and sorghum under semi arid conditions, the effect of competition for water was more severe than shading effects. Castor was more effected by the hedgerows compared to cowpea and sorghum. The yield of crops decreased consistently and progressively as the age of tree increased (Singh *et al.*, 1986).

Chandrashekaraiah (1986) noticed higher moisture depletion under bamboo followed by Casuarina, sissoo, Eucalyptus and least under subabul. In another study at Dharwad (Karnataka), increased moisture depletion upto 9 per cent nearer the teak, Eucalyptus and Casuarina tree lines was noticed compared to away from the tree line and greater moisture depletion upto 6-m under Eucalyptus (Bhat, 1988).

A study of five commonly grown agroforestry tree species with maize as intercrop showed that majority of their fine roots (<2 mm) occurred in the top layers of the soil (Jonsson *et al.*, 1988).

*Eucalyptus tereticornis* extracted 5 times more moisture than mustard from the 0 – 150-cm soil profile (Malik and Sharma, 1990). In another study depletion of moisture in the upper surface of soil was higher under

*Eucalyptus hybrid* compared to *Casuarina*, *Dalbergia sissoo* and *Acacia nilotica* (Bhaskar *et al.*, 1991). Thomas and Mead (1992) observed that roots of two years old *Pinus radiata* took upto 20 per cent labelled N fertilizer applied to adjoining arable crops indicating its competition with arable crops even at early stage.

The organic carbon content of soil increased due to cropping of clusterbean with *Acacia tortalis* as compared to pearl millet (Sharma *et al.*, 1994). Available soil nitrogen was higher by 24 to 84 per cent in trees viz. *Tectona grandis*, *Cassia siamea*, *Casuarina equisetifolia*, *Ceiba pentandra*. The increased phosphorus content associated with *Tectona grandis* was estimated to be 28 kg per ha (Parthiban and Vinay Rai, 1994).

The primary effect of competition with roots is for nutrients and water. Growing sissoo trees proved beneficial in improving the site condition by increasing carbon and nitrogen in rainfed conditions (Subramanyan *et al.*, 1996).

Growth of plants depends on water and nutrient availability in addition to several other factors. Nutrient availability depends on water availability. The uptake of nitrogen, phosphorus and potash is reduced by moisture stress. Water deficit causes reduction in photosynthetic rate and chlorophyll content in leaves (Sankara Reddi and Yellamma Raddi, 1995).

#### **2.2.4 Effect of trees on growth and yield of crops**

The field crops such as maize, ragi and rice have performed better when grown in association with the *Dalbergia sissoo* and *Tectona grandis* (Mishra, 1979). The study conducted on compatibility of crop and tree association by Khattak *et al.* (1980) revealed that grain yields of wheat

reduced significantly with *Eucalyptus comaldulensis*, *Populus deltoides* and *Bombax ceiba* compared to wheat yield with *Dalbergia sissoo*. King *et al* (1981) reported that the maize yield was significantly lower from rows adjacent to subabul due to shade.

Dhillon *et al.* (1982) reported that the yield of wheat, barely, potato and rice was adversely affected due to *Eucalyptus* plantation at Ludhiana. The adversity of the *Eucalyptus* varied with the direction of tree planting, season and purpose for which the crop was grown. Rice and maize were grown in teak planted at 4x2m, 5x2m and 6x2m spacing for five years without reduction of yields (Arifin, 1983). Balasubramanian (1983) reported that the yam yield was reduced in alley cropping due to shade from *Luecaena* hedgerows.

Dry matter accumulation was lower due to decreased photosynthesis in paddy under shaded conditions (Hesse, 1984). Maize yields were reduced when grown in teak planted at 1.8 x 1.8 m due to poor light availability to maize (Vericumbe and Okali, 1985). Reduced yields of cowpea adjacent to *Calliandra* hedgerows were due to shading (Girchuru and Kang, 1989). Maize yields were reduced in the vicinity of the hedgerows of *Leucaena* (Lal, 1989).

Gajaneni and Jordan, (1989) reported that field crops were grown without any reduction in yield under 15-20 years old teak plantation of 8x8 m spacing in Indonesia. Parvez Ahmed (1989) reported significant lower yields of crops adjoining *Eucalyptus* tree due to the shade and low soil moisture content and yield loss increased with increase in the age of the trees. Groundnut yield reduction was minimum with *Dalbergia latifolia* (18.8%) followed by teak (20.4%) and *Eucalyptus* (41.6%) in four years of planting under irrigated condition (Nadagoud, 1990). The effect of 3.5 years old

*Eucalyptus tereticornis* on crop yield next to the tree line showed 47 and 37 per cent yield reduction, respectively, in mustard and wheat, when grown at a distance of less than 10m from the tree line (Malik and Sharma, 1990).

The yields of the pearl millet, cluster bean, greengram and sesamum under scattered *Prosopis cineraria* trees (20-80 trees/ha) were higher than in open field. The higher yield of agriculture crops under these trees was attributed to improvement of soil fertility and conservation of moisture (Puri *et al.*, 1994).

Nissen *et al.* (1999) reported that yield of cabbage planted near nine month old *Eucalyptus torrelliana* declined as a result of both shading and competition especially for moisture.

Marigoudra (2001) noticed no adverse effect on growth and yield of paddy due to associated teak plants during first year of planting.

#### **2.2.5 Effect of tree distance on growth of associated crops**

The studies on the effect of boundary planting with *Prosopis juliflora* under semi arid condition of India showed that the yields of sorghum was adversely affected up to a distance of 30 m from the tree line due to competition offered by the roots of *Prosopis juliflora* for moisture and nutrients. The maximum root distribution was observed at 0 – 5 m distance from tree in the top 20-cm soil layer and declined progressively thereafter. The soil moisture and also the yield increased with the distance from the tree line (Prajapathi *et al.*, 1971).

Dhillon *et al.*, (1982) noticed that *Eucalyptus* reduced the yield of wheat, barely, potato and rice was upto a distance of 32 m away from the tree base. The per cent reduction in the crop yield varied from 64.0 at 1 m to 1.0

at 28 m away from the tree line. The crops sown on the southern side of the tree line had the maximum effect upto a distance of 15.09 m. The yield reduction in this case varied from the 50.1 per cent at 1 m to 0.3 per cent at 16 m from the tree line. The distance upto which *Eucalyptus* trees affected the crop yield depended on the tree crown, cropping season and types of crops. Hence, management of trees with respect to their canopy and the rooting habit appears to be very important in minimizing the adverse effects.

King *et al* (1981) stated that maize yield was significantly lower in rows adjacent to subabul due to shade. At Dharwad, grain yield of maize was less with teak (42%) and bamboo (51%) as compared to control (Chandrashekaraiah, 1986). Grain yield of agriculture crops decreased when grown in association with *Casuarina equisetifolia*, *Adina cardifolia* and *Gmelina arborea*. The reduction in the grain yield was more under *Casuarina* when compared to other two (Mehta and Mandal, 1986). The productivity of moong bean was increased with *Prosopis cineraria* and *Acacia albida* as compared to sole cropping (Shankaranarayana *et al.*, 1987) at Jodhpur.

Lowest yield reduction of rabi-sorghum was with teak and subabul and the yield reduction decreased with increasing distance from the tree line (Ital, 1987). Crops like maize and cassava were grown without any loss of yields with teak based agroforestry system in Georgia, USA (Wojtkwski *et al.*, 1988). *Eucalyptus* trees planted on field boundaries reduced the yield of annual crops by 46 and 47 per cent in the 9<sup>th</sup> and 10<sup>th</sup> year planting respectively (Ahmed, 1989). Sharma and Singh (1992) reported increased wheat grain yield of about 10.63 kg in a zone of 15m from *Populus deltoides* tree line. Sharma (1996) reported that *Dalbergia sissoo* affected the wheat

area of 220 m<sup>2</sup> and 440 m<sup>2</sup> respectively, when planted as boundary plantation. Yield reduction was 21.2 and 101.0 kg in wheat and paddy, respectively.

Mohammed afjal and Hafeez *et al.* (1999) found that crop yields were reduced up to 18.29 m from *Dalbergia sissoo* and 19.51m from mango but reductions were much higher with mango than with sissoo.

Hooda *et al.* (1999) reported that better moisture and increased soil fertility led to the higher number of plant per m<sup>2</sup>, pods per plant, seeds per pod, 100 seed weight and seed yield of chickpea under a tree canopy compare to chickpea alone. The favorable effects of trees were observed only from 5 to 13 m distances from the tree base and no influence beyond 13m. Seed yield up to 13 m distance was 141.9, 33.31 and 54.43 per cent higher under *Prosopis cineraria*, *Tecomella undulata* and *Acacia nilotica*, respectively.

## **2.2.6 Effect of field crop on growth attributes of associated trees**

Nair (1980) reported that black pepper, cocoa and medicinal plants were grown with teak without affecting its growth. Teak growth and yields of paddy and pulse crops were not much affected by their combinations (Kappa, 1988). Early growth of tree was not affected by crop combination viz. rice, sorghum, groundnut and sesame (Watanable *et al.*, 1988).

Teak growth was affected when grown with turmeric in West Bengal (Lahiri, 1989). Teak plantations were established without causing indurance to its growth by combining with paddy (Chantrappa, 1991). Agricultural crops or pastoral crops with teak didn't affect height, mean annual increment *in height* and dbh of teak (White, 1991).

In Java Social Forestry Programme (JSFP), degraded forest land was assigned to tribal for growing of crops and teak. The survival of teak seedlings exceeded 90 per cent and crops yields were not much affected by it (Sunderlin, 1992).

Teak was much benefited by growing of crops (berseem and gram) in the interspace of trees for initial six years as additional care (water/nutrient/management) was given for field crops (Dagar *et al.*, 1995). Robert *et al* (1998) reported that teak plantations intercropped with paddy, groundnut and pulses had no deleterious effect on either teak or field crops for the first two to five years.

Mutanal (1998) reported that extent of decrease in the basal area of teak was 19.1 and 13.9 percent in sorghum + teak and teak with grass and subabul, respectively, and 36.7 and 32 per cent in groundnut + teak and teak with grass and subabul. The poor growth of teak with pasture crops was attributed to the severe competition posed by pasture crops for moisture and nutrients. Marigoudra (2001) recorded no negative effects on growth attributes of one year old teak when grown along with paddy.

## MATERIAL AND METHODS

### **III MATERIALS AND METHODS**

A field experiment was carried out during 2001-2002 to know the effect of nutrient application on teak grown on the bunds of upland paddy field and interaction effect of teak on paddy and vice versa. The details of the materials used and methods adopted in the present investigation are described in this chapter.

#### **3.1 Location of the experimental site**

The experiment was conducted at the Agricultural Research Station (ARS), Mundgod, which is situated at 14°58' N latitude, 70° 2' E longitude and at an altitude of 563.9 m above MSL. The research station is located in hill zone (zone-9) of Karnataka.

#### **3.2 Climate**

The data on climatic parameters viz., rainfall, number of rainy days, maximum and minimum temperature during the cropping period and the mean of last 16 years (1985-2000) recorded at meteorological observatory at ARS, Mundgod are presented in Table 1 and depicted in Fig-1 and Fig-2.

The mean annual rainfall for 16 years at ARS, Mundgod was 1165.16 mm. Maximum rainfall was received in July (355.3 mm) followed by October (239.1 mm). Of the total rainfall, nearly 90 per cent was received from June to October. The total rainfall of 793.04 mm was received during 2001-2002, which was 369.7 mm less compared to normal rainfall of 1165.16 mm. The numbers of rainy days were 84 during 2001-2002, which were more by 6.7 days compare to normal number of rainy days (77.3).

Table 1. Rainfall and temperature data for the period from April 2001 to March 2002 and mean of last 16 years (1985-2000) at ARS, Mundgod.

| Months    | Rain fall (mm) |         | Number of rainy days |         |         | ** Temperature (°C) |         |         |
|-----------|----------------|---------|----------------------|---------|---------|---------------------|---------|---------|
|           | *Mean          | 2001-02 | *Mean                | 2001-02 | 2001-02 | Maximum             |         | Minimum |
| April     | 22.9           | 78.0    | 1.7                  | 5       | 5       | *Mean               | 2001-02 | 2001-02 |
| May       | 79.9           | 27.2    | 5.0                  | 7       | 7       | 35.2                | 34.1    | 21.5    |
| June      | 206.6          | 213.0   | 14.7                 | 15      | 15      | 32.3                | 33.4    | 21.9    |
| July      | 355.3          | 155.6   | 20.0                 | 26      | 26      | 25.9                | 27.4    | 21.2    |
| August    | 172.5          | 177.6   | 17.6                 | 19      | 19      | 25.0                | 23.6    | 20.8    |
| September | 64.0           | 42.2    | 6.7                  | 5       | 5       | 25.4                | 22.9    | 20.5    |
| October   | 239.1          | 80.8    | 9.7                  | 5       | 5       | 26.7                | 23.4    | 20.5    |
| November  | 16.6           | --      | 1.6                  | --      | --      | 27.5                | 24.0    | 20.0    |
| December  | 7.8            | 3.6     | 0.3                  | 1       | 1       | 27.7                | 23.8    | 17.6    |
| January   | 0.4            | --      | --                   | --      | --      | 27.2                | 25.2    | 15.0    |
| February  | --             | 17.4    | --                   | 1       | 1       | 29.4                | 28.6    | 14.2    |
| March     | --             | --      | --                   | --      | --      | 31.9                | 28.0    | 16.0    |
| Total     | 1165.1         | 795.4   | 77.31                | 84      | 84      | 35.0                | 28.9    | 18.7    |
|           |                |         |                      |         |         | --                  | --      | --      |

\* Means of 16 years

\*\* Pertains to Agriculture Research Station, Prabunagar situated in hill zone (zone-9) of Karnataka.

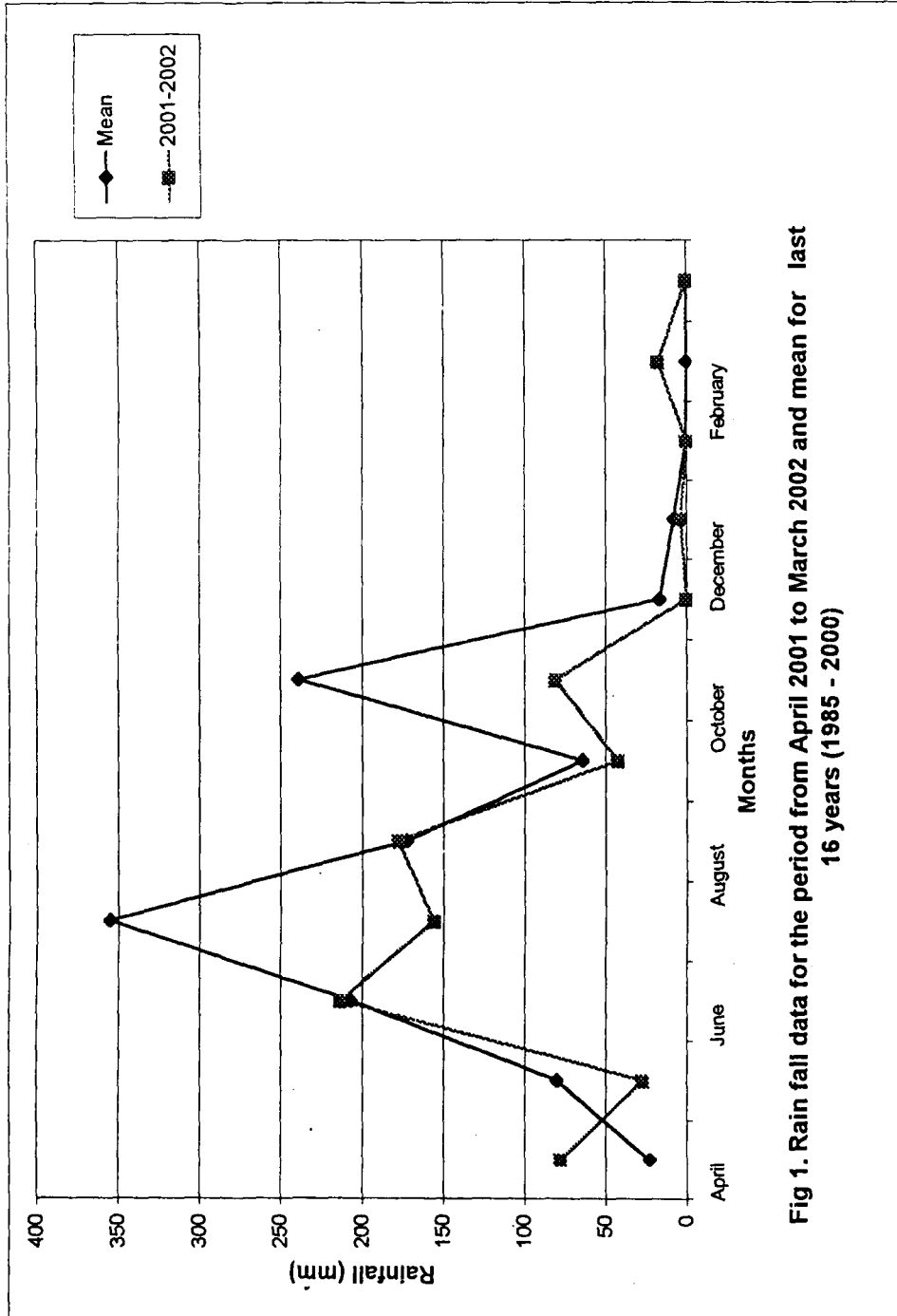


Fig 1. Rain fall data for the period from April 2001 to March 2002 and mean for last 16 years (1985 - 2000)

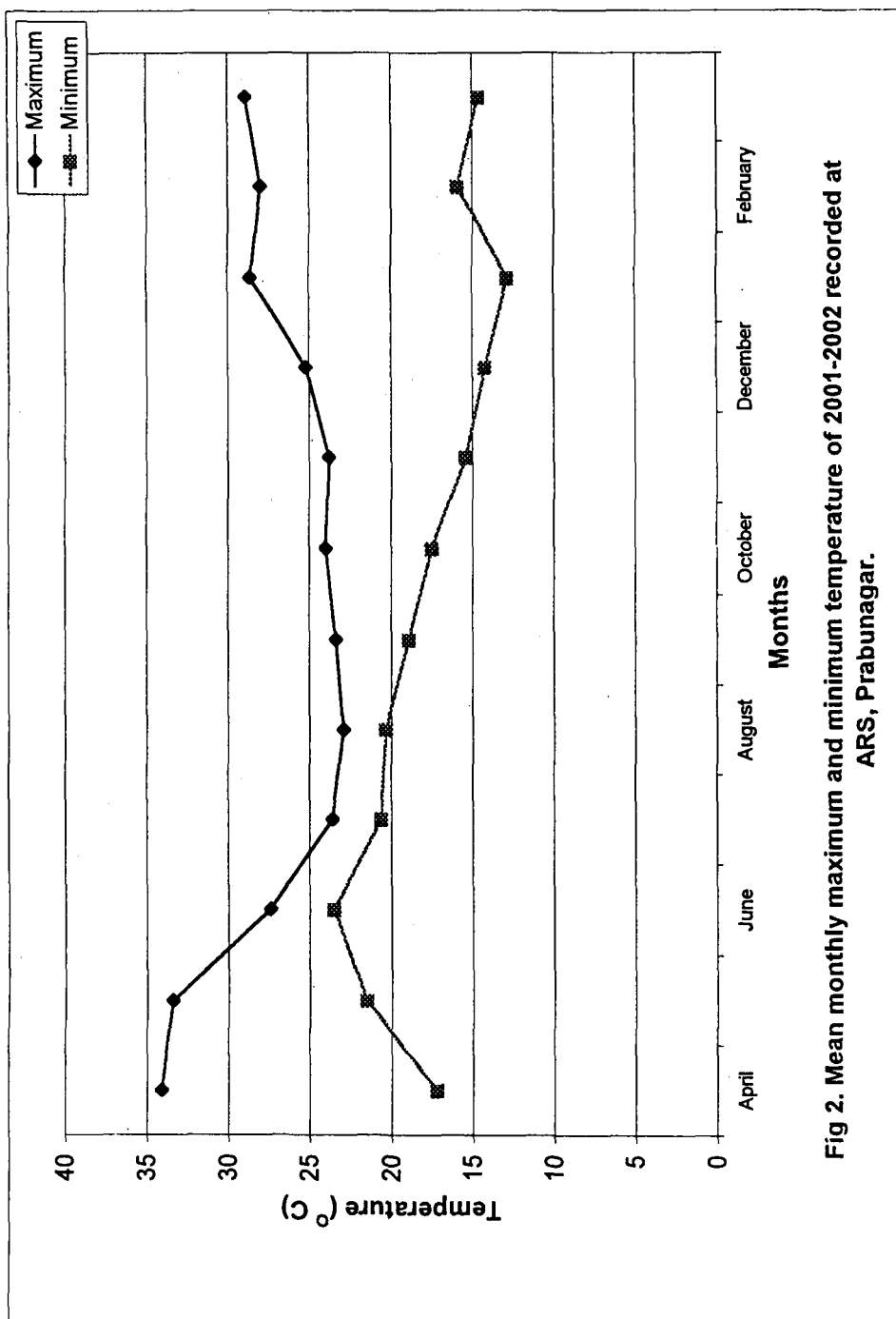


Fig 2. Mean monthly maximum and minimum temperature of 2001-2002 recorded at ARS, Prabunagar.

Table 2. Physical and chemical properties of the soil of the experiment site.

| Properties                                      |       | Methods                                  |
|-------------------------------------------------|-------|------------------------------------------|
| 1. Physical properties                          |       |                                          |
| Sand (%)                                        | 30.68 | Hydrometer method (Piper, 1966)          |
| Silt (%)                                        | 18.80 | Hydrometer method (Piper, 1966)          |
| Clay (%)                                        | 49.60 | Hydrometer method (Piper, 1966)          |
| Bulk density (g/cc)                             | 1.35  | Core sampling method                     |
| 2. Chemical properties                          |       |                                          |
| pH                                              | 6.5   | 2.5 digital pH meter (Jackson, 1967)     |
| EC (ds/m)                                       | 0.052 | 1:2.5 Conductometer (Jackson, 1967)      |
| Organic carbon (%)                              | 1.89  | Walkley and Black's wet oxidation method |
| Available P <sub>2</sub> O <sub>5</sub> (kg/ha) | 43.65 | Olsen's method (Jackson, 1967)           |
| Available K <sub>2</sub> O (kg/ha)              | 288.5 | Ammonium acetate method (Black, 1965)    |

Table 3. Details of spacing and cultural operations

| Details                                                        | Teak                   | Paddy                 |
|----------------------------------------------------------------|------------------------|-----------------------|
| Spacing                                                        | 1m (intra - row)       | 20 cm (inter-row)     |
| Fertilizer N, P <sub>2</sub> O <sub>5</sub> , K <sub>2</sub> O | As per treatment       | 40:20:20 NPK kg/ha    |
| Date of planting and sowing                                    | 14/6/2000              | 23/6/2001             |
| Weedicide application<br>Glyphosate (0.5 %)                    | 18/6/2001 & 19/8/2001  | -----                 |
| Date of harvesting                                             | -----                  | 14/11/2001            |
| weeding                                                        | 8/7/2001, & 20/11/2001 | 15/7/2001 & 20/8/2001 |

The highest mean monthly maximum temperature (35.2° C) and lowest mean monthly minimum temperature (14.2° C) were observed in April and January, respectively, during last 16 years. The highest and lowest mean monthly maximum temperature was in April (34.1° C) and August (22.9° C) during 2001-2002. The mean monthly minimum temperature was highest in June (23.5 ° C) and lowest in January (12.8° C).

### **3.3 Soils of the experimental site**

The experiment was conducted on medium deep and clayey soils with fairly good drainage. Data on physical and chemical properties of the soil of experimental site are provided in Table 2.

### **3.4 Previous crop grown on experimental site**

During 2000-2001, paddy (var. Doddiga) was grown. Recommended package of practices for paddy under rainfed conditions were adopted. The land is laid out into bench terraces with an average gradient of 40 cm. The average width of each terrace is 30 m. During previous year, the bunds of terraces were planted with teak seedlings and fertilizer levels as indicated in section 3.5.1 B were applied as a part of studies made by Marigoudra (2001).

### **3.5 Experimental details**

The details of treatments of the field experiment conducted during 2001-2002 are mentioned below. The other experimental details like planting, spacing, weeding, fertilizer and pesticides application etc. are furnished in Table 3. Fertilizer treatments were imposed on already existing 1 year old teak plants planted on terrace bunds (Plate 1) on fixed plot basis i.e. the plots which received certain fertilizer level in the previous year were imposed with

the same levels of fertilizer. Adjacent to teak rows, paddy crop (kharif crop) was grown (30 cm away from the teak rows) (Plate 2).

### 3.5.1 Treatments

There were 2 main plots and 7 sub plots

#### A. Main plots (Distance from teak row)

$D_1 = 0$  to 2 m

$D_2 = 2$  to 4 m

#### B. Sub plots (Fertilizer levels to teak)

$F_1$ - Control

$F_2$ - FYM alone (2.5 kg/plant)

$F_3$ - FYM + 10:5:10 NPK g per plant

$F_4$ - FYM + 15:7.5:15 NPK g per plant

$F_5$ - FYM + 20:10:20 NPK g per plant

$F_6$ - FYM + 25:12.5:25 NPK g per plant

$F_7$ - FYM +30:15:30 NPK g per plant

For convenience in presentation,  $P_2O_5$  and  $K_2O$  are mentioned as P and K respectively in subsequent sections.

Two separate plots in each replication i.e. one with only teak on bunds (no paddy crop in adjacent area and was treated with FYM + 20:10:20 NPK g/plant) (Plate 3) and other with only paddy (no teak on bunds) were maintained to study effect of paddy on teak.

### 3.5.2 Design, Layout and Replication

The experiment was laid out in split plot design. Three replications were maintained. However, effects of fertilizer levels on perennial component (teak) of the agroforestry system were analysed using the concept of

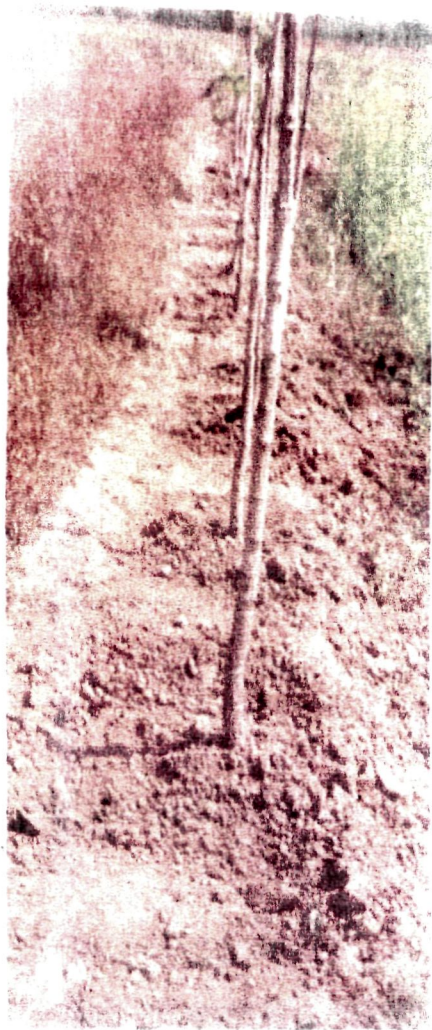


Plate 1. Plate showing teak plants planted on terrace bunds

Plate 2. Plate showing paddy crop in association with bund planted teak plants

Plate 3. Plate showing teak plants on terrace bunds with no paddy crop in the near vicinity

Plate 4. Plate showing weeding and soil working in teak plants after harvest of the adjacent paddy crop

N→

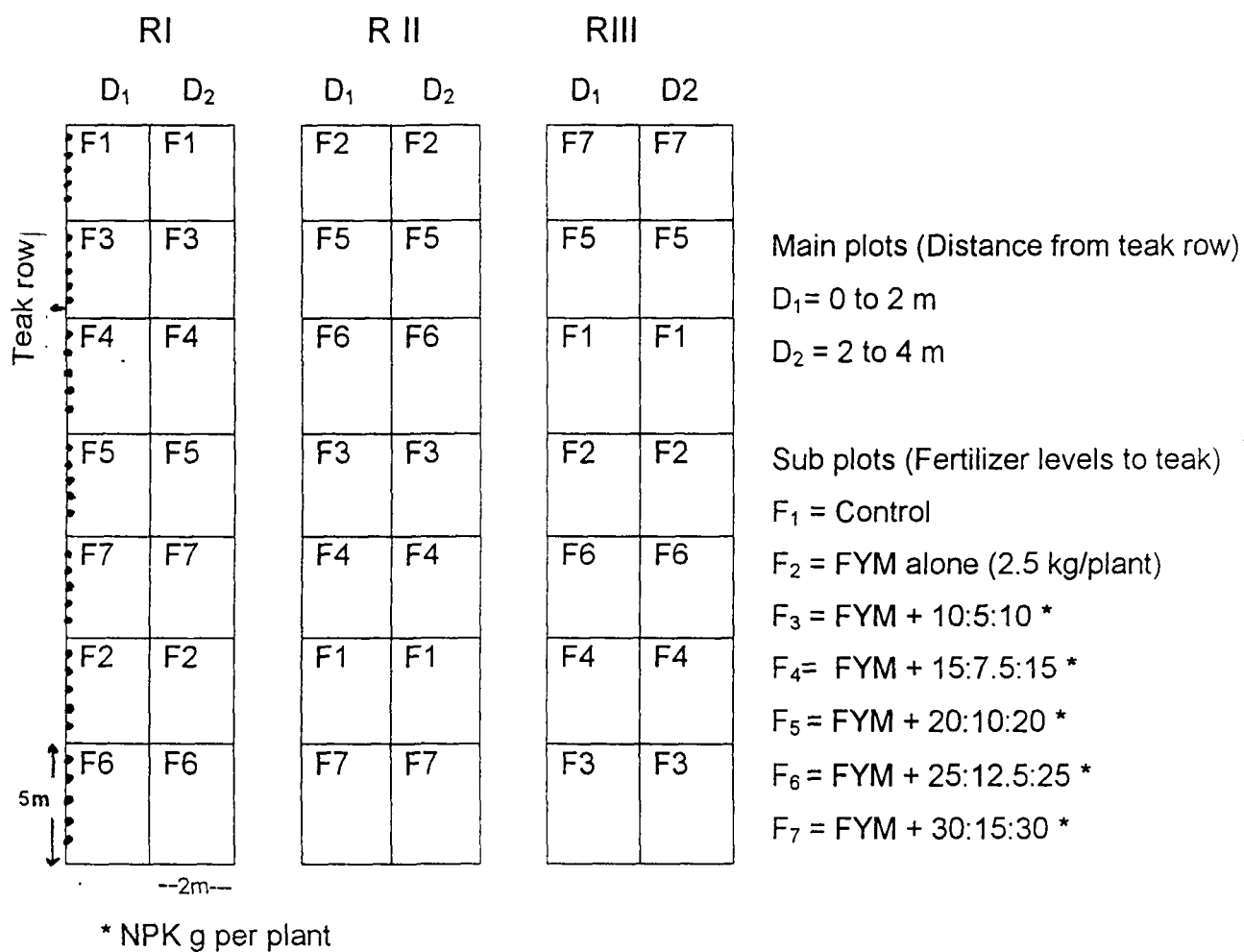


Fig 3. Plan of layout of experiment

Randomized Block Design; where as, interaction effects of teak on paddy were analysed using Split plot design i. e., distance from tree row as main plot and fertilizer levels to teak as sub plot.

### **3.5.3 Plot size**

Gross: 5 x 2 m = 10 sq. m

Net: 3 x 2 m = 6 sq. m

## **3.6 Description of crop variety/tree species**

### **3.6.1 Paddy variety**

Doddiga variety of paddy was used for sowing. It is a medium duration (135 days) tall variety with yield potential of 39 q per ha. It is locally grown in upland paddy areas of hill zone. The average grain length and width are 5.6 and 2.4 mm, respectively. It is moderately resistant to blast.

### **3.6.2 Teak**

Teak is a large deciduous tree with a long clean bole. It is found in various geographical formations and on soils with pH 6.5-7.5. It thrives well in areas with an annual rainfall of 1000-1500 mm as in southern tropical, moist and dry deciduous forests. It suits excellent for furniture, cabin making, decorative veneer, plywood and all sorts of constructions. The planting stock used was obtained from State Forest Department Nursery at Bachanaki (near Mundgod)

## **3.7 Cultural operations**

### **3.7.1 Land preparation**

Before the onset of monsoon, the land was ploughed once after the harvest of preceding paddy crop. In the month of May, the clods were

crushed and land was brought to fine tilth by harrowing and smoothening with the wooden planks.

### **3.7.2 Sowing**

Paddy seeds were sown in the area adjacent to teak plants in all the treatment (30 cm away from teak row) using seed-cum fertilizer drill. Inter row spacing of 20 cm was maintained.

### **3.7.3 Farm Yard Manure and fertilizer application**

Fertilizer treatments were imposed on one year old teak plants which were planted on the bunds during June 2000. Farm Yard Manure and inorganic fertilizers as per the treatment were applied soon after the onset of monsoon. Required quantity of FYM was applied around the teak plants at 15 cm distance and 10 cm depth and was thoroughly covered with soil.

Inorganic fertilizers were applied in the form of urea, di-ammonium phosphate and muriate of potash. Full quantities of P, K and 50 per cent of N as per the treatments were applied around the teak plant (2 weeks after planting) in the ring made at 10 cm distance from the base of the plant and 5 cm deep in to soil. The remaining fifty per cent of N, as per the treatments, was applied two months after the basal application. In plots maintained to study tree crop interaction, fertilizer of 2.5 kg FYM + 20:10:20 NPK g per plant was used.

### **3.7.4 After care**

Post emergence spray of glyphosate at 5 ml per liter of water was applied to control weeds on bunds. Due care was taken to protect the seedlings from herbicide drifts. Weeds around teak seedlings were removed by hand weeding as and when required. Two hand weedings were done to

control weeds in paddy crop. No major insect pests or diseases were noticed in both paddy and teak. After harvesting of paddy, periodical removal of weeds around teak plants was done and the bund area was kept clean (Plate 4).

### **3.7.5 Harvesting**

Harvesting of paddy crop was done at full maturity on date indicated in the Table 3. All the plants in each net plot were cut at ground level and bundled. The grains were separated by hand threshing and cleaned, dried and weighed. Dried straw weight was also recorded.

## **3.8 Collection of experimental data**

### **3.8.1 Observations on teak**

In each gross plot, there were 5 teak plants in a row with an intra row spacing of 1m. Three in the middle of plot under each treatment were marked with tags. Observation on growth parameters was recorded on such plants and average data per plant was calculated. The area from the base of these plants upto 2 m and 2 to 4 m (where paddy was grown) formed the net plots of the experiment. The observations were recorded at 2 months interval upto 8 months of treatment imposition.

#### **3.8.1.1 Plant height**

The plant height was measured from the base of the plant to the tip of the main stem and expressed in cm.

#### **3.8.1.2 Collar diameter (cm)**

The diameter of the stem at collar region was measured with the help of vernier caliper and expressed in cm.

### **3.8.1.3 Number of leaves**

Fully opened green leaves were counted and mean number of leaves per plant was calculated. Further observation after 18 months of planting were not taken due to coincidence of teak growth with winter.

### **3.8.1.4 Number of nodes on main stem.**

Fully developed nodes on the main stem were counted in each tagged plant and average number of nodes per plant was worked out.

### **3.8.1.5 Leaf area (cm<sup>2</sup>)**

Leaf area was calculated as per the procedure suggested by Strikler *et al.* (1961). The length and breadth of all the leaves including small, medium and big were measured with the help of scale. A factor (0.622) was worked out with the help of planimeter reading of randomly selected hundred leaves from the experimental plants. Using this factor, the leaf area per plant was computed based on length and breadth measurement of each fully opened leaf and expressed in cm<sup>2</sup>. Further observations after 18 months of planting was not taken as there was leaf shedding due to coincidence of teak growth with winter.

### **3.8.1.6 Crown diameter**

Crown diameter was measured in two directions perpendicular to each other by holding the tape coinciding the last tip of the branches. Average of the two was taken as crown diameter and expressed in cm. Further observations, after 18 months of planting were not taken due to coinciding teak growth with winter.

### 3.8.1.7 Crown spread (cm<sup>2</sup>)

The crown spread was calculated by using following formula

$$CS = CD^2 \pi / 4 \text{ where, } CS = \text{Crown spread}$$

CD = Crown diameter

### 3.8.1.8 Internodal length

Length of the each internode was measured and then mean of internodes was worked out and expressed in cm.

### 3.8.1.9 Net increment in growth attributes of teak

Net increment with respect to plant height, collar diameter, number of leaves per plant and main stem nodes per plant was calculated by deducting the initial growth of parameters from the corresponding values of final growth.

### 3.8.1.10 Biomass production

During final observations, one teak plant from each replication (which represent average value) was cut at ground level. The cut plant was partitioned into leaves, branches and main stem. The plants parts were oven dried separately at 70° C. to a constant weight and oven dried weight was recorded. Total biomass production per plant and its distribution into different parts was worked out.

### 3.8.1.11 Main stem volume (cm<sup>3</sup>)

The main stem was segmented into equal length of 30 cm and volume of the each segment was calculated based on mid girth and length and summed up to get total volume of the main stem.

### 3.8.1.12 Form factor

Form factor was calculated using the following relationship.

$$\text{Form factor} = \frac{\text{Actual volume of main stem}}{\text{Volume of the cylinder of equal basal area and height}}$$

### 3.8.1.13 Fertilizer use efficiency (FUE)

The total biomass yield was used to calculate the FUE by adopting the formula given by Banerjee *et al.*, 1999

$$\text{FUE (\%)} = \frac{\text{Biomass in treatment} - \text{Biomass in control}}{\text{Biomass in control}} \times 100$$

### 3.8.2 Observations on paddy

The data on growth parameters of paddy were collected at three stages i.e. vegetative (60 DAS), grain filling (120 DAS) and at harvest phase. Five plants were selected randomly in each plot and observations were recorded on these plants, and average data per plant was calculated.

#### 3.8.2.1 Plant height (cm)

Plant height was measured from base of the plant to tip of stem and expressed in cm

#### 3.8.2.2 Dry weight per plant (g)

Five plants selected randomly (as explained in 3.8.2) were cut close to ground level and oven dried at 70°C to constant weight and dry weight was recorded.

#### 3.8.2.3 Tillers per meter row length

Tillers were counted in one meter row length at 5 spots in each net plot and then average was worked out.

#### 3.8.2.4 Thousand grain weight (g)

Thousand grains from each net plot were counted, weighed and expressed in gram.

### 3.8.2.5 Grain yield per ha (kg)

Grain yield in each plot (including yield of sampled plots) was recorded as explained 3.7.5. Based on this data, grain yield per hectare was computed and expressed in kg.

### 3.8.2.6 Straw yield per ha (kg)

Based on the straw yield in each plot, straw yield per hectare was computed and expressed in kg.

### 3.8.2.7 Relative yield index

The relative yield index of paddy was calculated by using the formula as indicated by Singh *et al.*, (1986).

$$\text{Relative Crop Index} = \frac{\text{Yield of paddy grown with teak}}{\text{Yield of paddy grown without teak}} \times 100$$

## 3.8.3 Soil moisture

Soil auger was used to collect the soil samples in all the treatments. The soil samples were drawn by drilling holes upto 30 cm depth in each treatment at two and four meter distance from the teak lines. The moisture content of the samples was determined using gravimetric method and expressed in percentage.

## 3.8.4 Nutrient uptake

### 3.8.4.1 Nutrient uptake by teak

Plant samples collected during final observations were oven dried and ground in Willy Mill and were used for estimation of nitrogen, phosphorus and potassium contents. Uptake of N, P and K per plant was calculated based on nutrient content in plant and dry weight per plant. Nitrogen content in plant

was estimated by modified Kjeldahl method (Yoshida *et al.*, 1971), phosphorus and potassium content in plants were calculated following the procedure of Jackson (1967).

#### **3.8.4.2 Nutrient uptake by paddy**

Plant samples collected at harvest were ground in Willy Mill and composite sample (grain and straw) was used for estimation of nitrogen, phosphorus and potassium contents using procedure mentioned in 3.8.4.1. Uptake of N, P and K per hectare was calculated based on nutrient content in plant and dry weight per hectare.

#### **3.8.5 Statistical analysis**

The data collected from the experiments were analyzed statistically as described by Gomez and Gomez (1984). The level of significance used in 'F' and 't' tests was  $P = 0.05$ . The main value of main plot, sub plot and interaction effects were separately subjected to Duncan's multiple range test (DMRT) for analyzing teak paddy interactions by using the value of corresponding error mean sum of squares and degrees of freedom under M-STAT programme.

## EXPERIMENTAL RESULTS

## **IV EXPERIMENTAL RESULTS**

Results of the field experiment on effect of fertilizer levels on teak grown on the bunds of upland paddy and its interaction on associated paddy crop conducted at ARS, Mundgod during 2001-2002 are presented in this chapter.

### **4.1 Effect of fertilizer levels on teak**

#### **4.1.1 Growth attributes of teak**

Seven fertilizer levels including control and the application of FYM alone were imposed on one year old teak plants planted on the bunds of upland paddy area. Observations on teak were recorded at the interval of two months starting from 14 months after planting (MAP) upto 20 MAP.

##### **4.1.1.1 Plant height (Table 4)**

Plant height differed significantly due to different levels of fertilizer at all growth stages studied (Fig 4). At 14MAP, significantly higher plant height was recorded with FYM + 30:15:30 NPK g per plant (86.8cm) which was on par with treatments receiving fertilizer levels of F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub>. Plant height was lowest with control (50.6cm) which was on par with the treatment receiving FYM alone (52.7cm).

At 16 MAP, application of FYM + 30:15:30 NPK g per plant recorded significantly higher plant height (138.3cm) which was statistically on par with treatment receiving FYM + 25:12.5:25 NPK g per plant (134.0cm) and FYM + 20:15:20 NPK g per plant (131.4 cm). Significantly lower plant height was recorded in control (69.6 cm).

Similar trends in the height of teak due to application of different fertilizer levels were noticed at 18 and 20 MAP. Increase in plant height due to the application of FYM + 30:15:30 NPK g per plant over control and application of

Table 4. Plant height (cm) of teak at different stages of growth as influenced by fertilizer levels

| Treatments                                | 14 MAP  | 16 MAP  | 18 MAP   | 20 MAP  |
|-------------------------------------------|---------|---------|----------|---------|
| F <sub>1</sub> - Control                  | 50.6 b  | 69.6 b  | 83.8 c   | 87.9 b  |
| F <sub>2</sub> - FYM alone (2.5 kg/plant) | 52.7 b  | 77.7 b  | 88.6 c   | 92.0 b  |
| F <sub>3</sub> - FYM + 10:5:10*           | 57.6 ab | 80.6 b  | 97.0 bc  | 103.9 b |
| F <sub>4</sub> - FYM + 15:7.5:15*         | 59.6 ab | 81.2 b  | 109.8 b  | 116.9 b |
| F <sub>5</sub> - FYM + 20:10:20*          | 68.5 ab | 131.4 a | 156.9 ab | 163.1 a |
| F <sub>6</sub> - FYM + 25:12.5:25 *       | 69.0 ab | 134.0 a | 169.2 ab | 179.7 a |
| F <sub>7</sub> - FYM +30:15:30*           | 86.8 a  | 138.3 a | 182.3 a  | 196.7 a |
| Mean                                      | 64.01   | 102.11  | 126.09   | 134.32  |
| SEm +                                     | 8.62    | 17.55   | 15.25    | 14.20   |
| LSD (P = 0.05)                            | 26.57   | 49.88   | 46.99    | 41.20   |

\* NPK g per plant

MAP = Months after planting

LSD applicable to Duncan's multiple range test

Means followed by same subscripts do not differ significantly

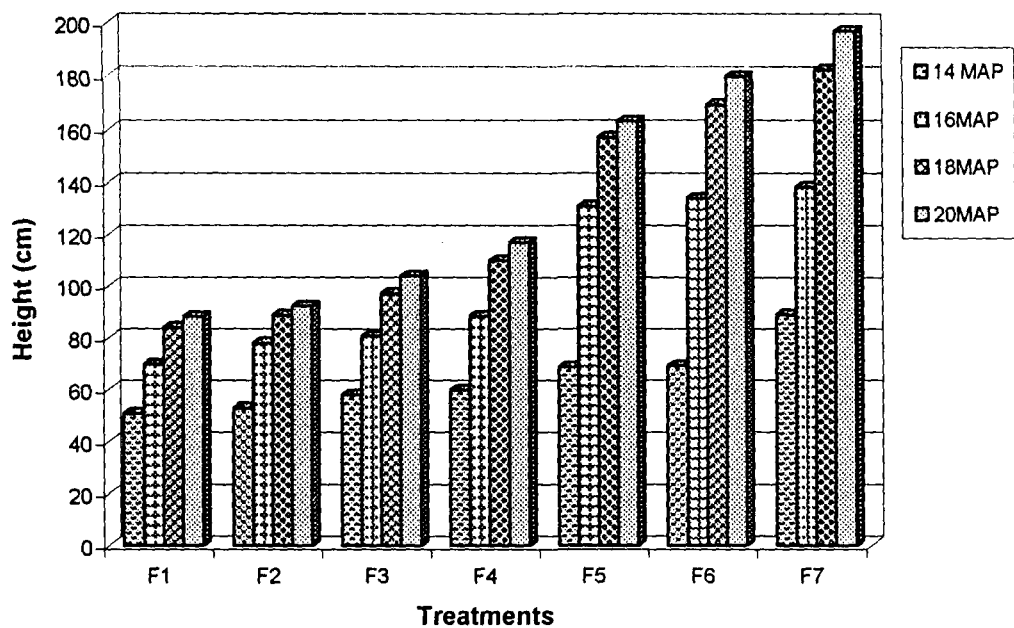


**Fig 4. Plant height (cm) of teak as influenced by different fertilizer levels imposed on teak**

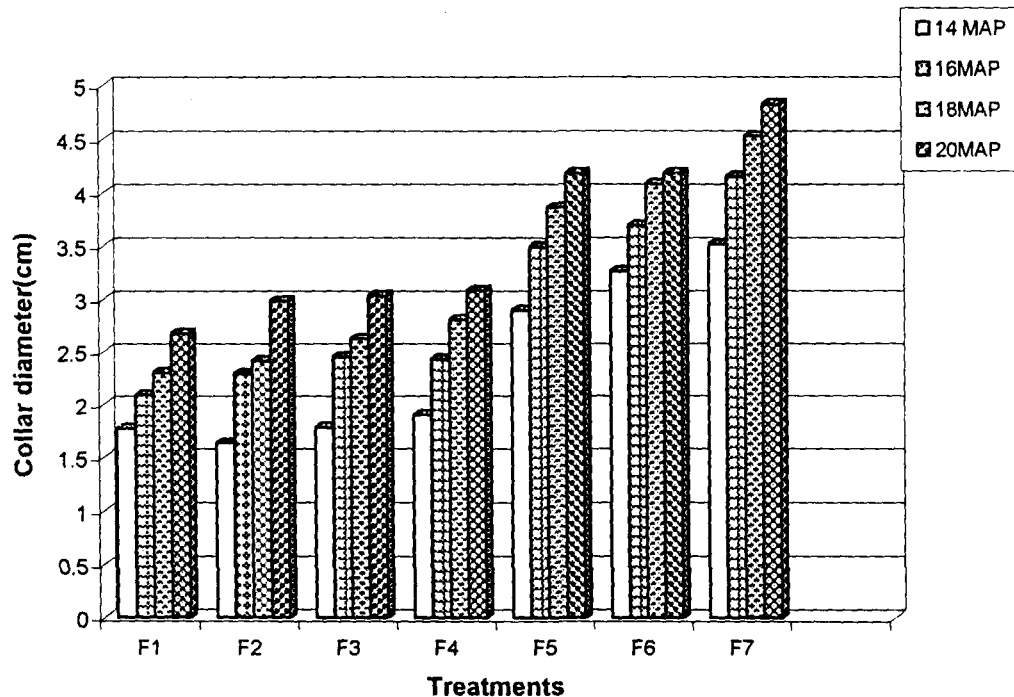


**Fig 5. Collar diameter (cm) of plant as influenced by different fertilizer levels imposed on teak**

FYM alone was 98.7 and 78.0, 117.5 and 105.8 and 123.8 and 113.8 per cent at 16, 18 and 20 MAP, respectively.

#### 4.1.1.2 Collar diameter (cm) (Table 5)

Significant difference in collar diameter of teak was observed due to different levels of fertilizer at all the stages of growth (Fig 5).

At 14MAP, significantly higher collar diameter was recorded (3.51 cm) with FYM + 30:15:30 NPK g per plant, which was on par with that of FYM + 25:12.5:25 NPK g per plant (3.26 cm) and FYM + 20:10:20 NPK g per plant (2.89cm). The lowest collar diameter was recorded in treatment with FYM alone (1.63cm) followed by control (1.77 cm), FYM + 10:5:10 NPK g per plant (1.78 cm) and FYM + 15:7.5:15 NPK g per plant (1.90 cm) which were at par.

At 16 MAP, significantly higher collar diameter was noticed with FYM + 30:15:30 NPK g per plant (4.15 cm) which was on par with FYM + 25:12.5:25 NPK g per plant (3.69 cm) and FYM + 20:10:20 NPK g per plant (3.49 cm). The lowest collar diameter was recorded in control (2.09 cm) which was statistically on par with treatments receiving fertilizer levels of  $F_2$ ,  $F_3$  and  $F_4$ .

At 18MAP, application of FYM + 30:15:30 NPK g per plant showed significantly higher collar diameter (4.53 cm) compared to rest of the treatments except the treatment with FYM + 25:12.5:25 NPK g per plant. The lowest collar diameter (2.30 cm) was in control, followed by treatment receiving FYM alone (2.42 cm).

At 20 MAP, significantly higher collar diameter (4.83 cm) was noticed with application of FYM + 30:15:30 NPK g per plant which was on par with FYM + 25:12.5:25 NPK g per plant and FYM + 20:10:20 NPK g per plant. The lowest collar diameter (2.67 cm) was in control, followed by treatments with  $F_2$ ,  $F_3$  and  $F_4$

Table 5. Collar diameter (cm) of teak at different stages of growth as influenced by fertilizer levels

| Treatments                                | 14 MAP | 16 MAP   | 18 MAP  | 20 MAP   |
|-------------------------------------------|--------|----------|---------|----------|
| F <sub>1</sub> - Control                  | 1.77 b | 2.09 c   | 2.30 c  | 2.67 c   |
| F <sub>2</sub> - FYM alone (2.5 kg/plant) | 1.63 b | 2.29 c   | 2.41 c  | 2.98 b c |
| F <sub>3</sub> - FYM + 10:5:10*           | 1.78 b | 2.45 b c | 2.62 c  | 3.03 b c |
| F <sub>4</sub> - FYM + 15:7.5:15*         | 1.90 b | 2.43 b c | 2.80 bc | 3.08 b c |
| F <sub>5</sub> - FYM + 20:10:20*          | 2.89 a | 3.49 a b | 3.86 ab | 4.18 a b |
| F <sub>6</sub> - FYM + 25:12.5:25 *       | 3.26 a | 3.69 a b | 4.08 ab | 4.18 a b |
| F <sub>7</sub> - FYM +30:15:30*           | 3.51 a | 4.15 a   | 4.53 a  | 4.83 a   |
| Mean                                      | 2.38   | 2.95     | 3.23    | 3.56     |
| SEm ±                                     | 0.205  | 0.34     | 0.395   | 0.39     |
| LSD (P = 0.05)                            | 0.634  | 1.04     | 1.22    | 1.23     |

\* NPK g per plant

MAP = Months after planting

LSD applicable to Duncan's multiple range test

Means followed by same subscripts do not differ significantly

Table 6. Number of stem nodes per plant at different stages of growth as influenced by fertilizer levels

| Treatments                                | 14 MAP  | 16 MAP  | 18 MAP  | 20 MAP   |
|-------------------------------------------|---------|---------|---------|----------|
| F <sub>1</sub> - Control                  | 2.11 c  | 6.99 b  | 8.22 b  | 9.85 c   |
| F <sub>2</sub> - FYM alone (2.5 kg/plant) | 2.87 bc | 7.06 b  | 9.66 b  | 11.02 c  |
| F <sub>3</sub> - FYM + 10:5:10*           | 2.87 bc | 7.94 b  | 10.00 b | 12.05 c  |
| F <sub>4</sub> - FYM + 15:7.5:15*         | 3.66 bc | 8.08 b  | 11.33 b | 12.99 bc |
| F <sub>5</sub> - FYM + 20:10:20*          | 5.74 b  | 14.22 a | 15.66 a | 16.28 ab |
| F <sub>6</sub> - FYM + 25:12.5:25 *       | 6.11 b  | 13.55 a | 16.66 a | 17.66 ab |
| F <sub>7</sub> - FYM +30:15:30*           | 9.66 a  | 14.55 a | 17.96 a | 19.04 a  |
| Mean                                      | 4.69    | 10.33   | 12.87   | 14.44    |
| SEm ±                                     | 1.08    | 1.57    | 1.48    | 1.61     |
| LSD (P = 0.05)                            | 3.31    | 4.85    | 4.56    | 4.96     |

\* NPK g per plant

MAP = Months after planting

LSD applicable to Duncan's multiple range test

Means followed by same subscripts do not differ significantly

which were statistically at par. The increase in collar diameter due to the application of FYM + 30:15:30 NPK g per plant was to the tune of 80.9 and 62.1 per cent over control and application of FYM alone, respectively.

#### **4.1.1.3 Number of main stem nodes per plant (Table 6)**

The number of stem nodes per plant differed significantly due to different levels of fertilizer at all stages of growth (Fig 6).

At 14 MAP, significantly more number of stem nodes (9.66) per plant was noticed with FYM + 30:15:30 NPK g per plant than rest of the treatments. Significantly lower number of main stem nodes per plant was recorded in control (2.11) which was on par with treatments  $F_2$ ,  $F_3$  and  $F_4$ .

The trend noticed in the number of stem nodes was similar at 16 and 18 MAP. At both the stages, the number of stem nodes was significantly higher with FYM + 30:15:30 NPK g per plant (14.55 and 17.96, respectively) which was on par with FYM + 25:12.5:25 NPK g per plant (13.55 and 16.66, respectively) and FYM + 20:10:20 NPK g per plant (14.22 and 15.66, respectively). Number of stem nodes was significantly lower in control at both stages (6.99 and 8.22, respectively) which was statistically on par with treatments receiving fertilizer levels of  $F_2$ ,  $F_3$  and  $F_4$ .

At 20 MAP, significantly higher number of stem nodes (19.04) was observed in case of FYM + 30:15:30 NPK g per plant which was on par with FYM + 25:12.5:25 NPK g per plant (17.66) and FYM + 20:10:20 NPK g per plant (16.28). The increase in number of main stem nodes with FYM + 30:15:30 NPK g per plant was 93.3 and 72.8 per cent over control and application of FYM alone, respectively.

Table 7. Number of leaves per plant at different stages of growth as influenced by fertilizer levels.

| Treatments                                | 14 MAP   | 16 MAP    | 18 MAP  |
|-------------------------------------------|----------|-----------|---------|
| F <sub>1</sub> - Control                  | 5.99 d   | 8.89 d    | 12.05 c |
| F <sub>2</sub> - FYM alone (2.5 kg/plant) | 6.11 d   | 10.89 cd  | 13.77 c |
| F <sub>3</sub> - FYM + 10:5:10*           | 7.94 cd  | 12.99 b-d | 13.88 c |
| F <sub>4</sub> - FYM + 15:7.5:15*         | 9.11 b-d | 17.00 a-c | 19.77 b |
| F <sub>5</sub> - FYM + 20:10:20*          | 11.77 bc | 18.22 a-c | 24.88 a |
| F <sub>6</sub> - FYM + 25:12.5:25 *       | 12.89 b  | 19.00 ab  | 25.22 a |
| F <sub>7</sub> - FYM +30:15:30*           | 18.32 a  | 21.99 a   | 25.55 a |
| Mean                                      | 10.31    | 15.43     | 13.31   |
| SEm ±                                     | 1.42     | 2.329     | 1.21    |
| LSD (P = 0.05)                            | 4.38     | 7.176     | 3.73    |

\* NPK g per plant

MAP = Months after planting

LSD applicable to Duncan's multiple range test

Means followed by same subscripts do not differ significantly

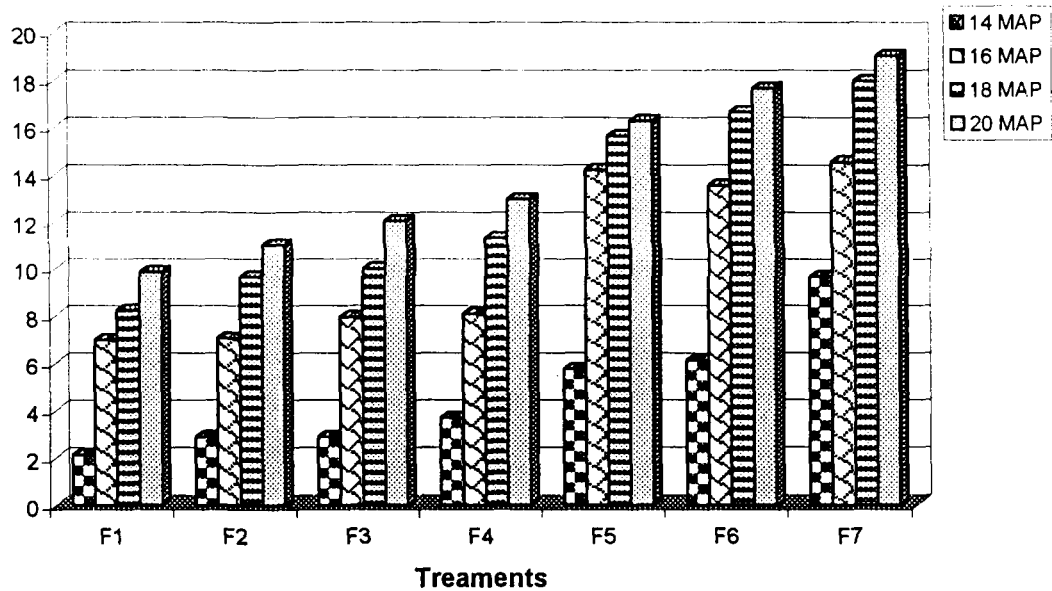


**Fig 6. Number of stem nodes per plant at different stages of growth as influenced by fertilizer levels**

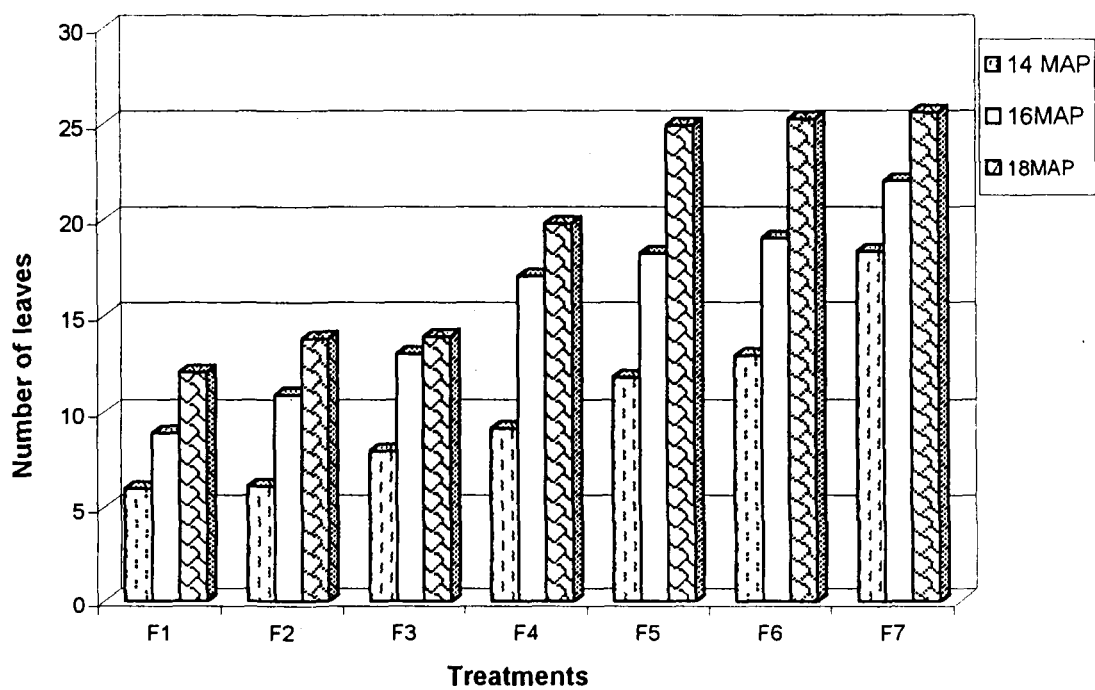


**Fig 7. Number of leaves per plant of teak at different stages of growth as influenced by fertilizer levels**

#### 4.1.1.4 Number of leaves per plant (Table 7)

Number of leaves at 14 MAP (Fig 7) was significantly higher (18.32) with the application of FYM + 30:15:30 NPK g per plant than rest of the treatments. The lowest number of leaves was recorded in control (5.99) which was statistically on par with the application of FYM alone (6.11), FYM + 10:5:10 NPK g per plant (7.94) and FYM + 15:7.5:15 NPK g per plant (9.11).

At 16 MAP, number of leaves was significantly more with FYM + 30:15:30 NPK g per plant (21.99) which was on par with FYM + 25:12.5:25 NPK g per plant (19.00) and FYM + 20:10:20 NPK g per plant (18.22). Number of leaves per plant was lowest in control (8.89 cm) followed by FYM alone (10.89) and FYM + 10:5:10 NPK g per plant (12.99) which were at par but differed significantly with other treatments.

At 18 MAP, application of FYM + 30:15:30 NPK g per plant recorded maximum number of leaves (25.55) per plant which was statistically on par with FYM + 25:12.5:25 NPK g per plant (25.22) and FYM + 20:10:20 NPK g per plant (24.88). The lowest number of leaves was with control (12.05) which was on par with treatments receiving  $F_2$  and  $F_3$  fertilizer levels. Application of FYM + 30:15:30 NPK g per plant showed 112.0 and 85.5 per cent increase in number of leaves as compare to control and FYM alone.

#### 4.1.1.5 Leaf area per plant (cm<sup>2</sup>) (Table 8)

Fertilizer levels had a significant influence on the leaf area per plant at all the growth stages studied (Fig 8).

At 14 MAP, the maximum leaf area per plant was observed with FYM + 30:15:30 NPK g per plant (5173.32 cm<sup>2</sup>) followed by  $F_4$ ,  $F_5$  and  $F_6$  which were on

Table 8. Leaf area (cm<sup>2</sup>) per plant at different stages of growth as influenced by fertilizer levels

| Treatments                                | 14 MAP     | 16 MAP     | 18 MAP     |
|-------------------------------------------|------------|------------|------------|
| F <sub>1</sub> - Control                  | 1561.19 d  | 2383.20 d  | 2683.30 c  |
| F <sub>2</sub> - FYM alone (2.5 kg/plant) | 2022.42 d  | 3074.81 cd | 3319.92 c  |
| F <sub>3</sub> - FYM + 10:5:10*           | 2083.76 d  | 3299.81 cd | 3495.52 c  |
| F <sub>4</sub> - FYM + 15:7.5:15*         | 2479.51 cd | 4617.44 c  | 5996.74 bc |
| F <sub>5</sub> - FYM + 20:10:20*          | 3532.10 bc | 6492.11 ab | 7128.33 ab |
| F <sub>6</sub> - FYM + 25:12.5:25 *       | 4775.65 ab | 7004.42 a  | 7467.31 ab |
| F <sub>7</sub> - FYM +30:15:30*           | 5173.32 a  | 7137.22 a  | 9381.62 a  |
| Mean                                      | 3090.47    | 4944.72    | 5489.85    |
| SEm +                                     | 413.66     | 423.54     | 849.10     |
| LSD (P = 0.05)                            | 1274.62    | 1305.00    | 2616.00    |

\* NPK g per plant

MAP = Months after planting

LSD applicable to Duncan's multiple range test

Means followed by same subscripts do not differ significantly

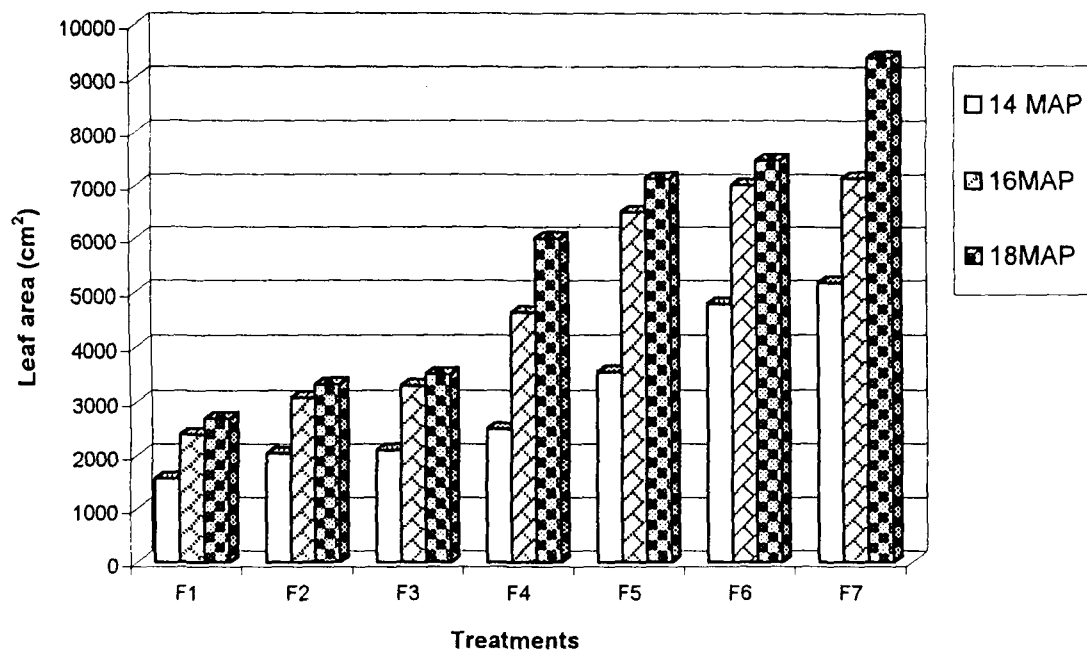


**Fig 8. Leaf area (cm<sup>2</sup>) per plant at different stages of growth as influenced by fertilizer levels**

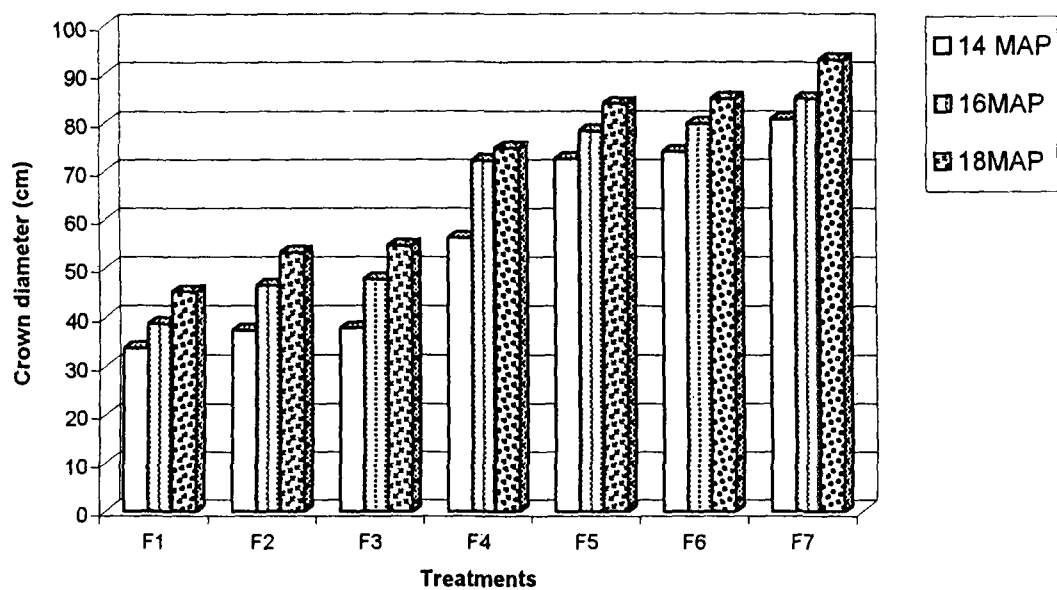


**Fig 9. Crown diameter (cm) per plant at different stages of growth as influenced by fertilizer levels.**

par but differed significantly with other treatments. The lowest leaf area was observed in control (1561.19 cm<sup>2</sup>) followed by FYM alone (2022.42 cm<sup>2</sup>).

At 16 MAP, FYM + 30:15:30 NPK g per plant showed significantly higher leaf area (7137.22 cm<sup>2</sup>) which was on par with FYM + 25:12.5:25 NPK g per plant (7004.4 cm<sup>2</sup>) and FYM + 20:10:20 NPK g per plant (6492.11 cm<sup>2</sup>). The lowest was recorded in treatment that received no fertilizers (2383.2 cm<sup>2</sup>) which was statistically on par with the application of FYM alone (3074.81 cm<sup>2</sup>) and 10:5:10 NPK g per plant (3299.81 cm<sup>2</sup>).

At 18 MAP, FYM + 30:15:30 NPK g per plant showed a significantly higher leaf area (9381.62 cm<sup>2</sup>) which was on par with F<sub>6</sub> and F<sub>5</sub>. Extent of increase in the leaf area with application of FYM + 30:15:30 NPK g per plant was 249.6 and 178.0 per cent over control and FYM alone, respectively.

#### **4.1.1.6 Crown diameter (cm) (Table 9)**

There was significant variation in crown diameter due to different fertilizer levels at all growth stages studied (Fig 9).

At 14 MAP, application of FYM + 30:15:30 NPK g per plant resulted significantly higher crown diameter (80.50cm) which was statistically on par with FYM + 25:12.5:25 NPK g per plant (73.83 cm) and FYM + 20:10:10 NPK g per plant (72.40 cm). The lowest crown diameter was noticed in the control treatment (33.66cm) followed by FYM alone (37.26) and FYM + 10:5:10 NPK g per plant (37.73) which were at par but differed significantly with rest of the treatments. Similar trend was noticed during 16 and 18 MAP.

Application of FYM + 30:15:30 NPK g per plant showed 106.1 and 74.9 per cent increase in crown diameter over control and FYM alone, respectively, at 18 MAP.

Table 9. Crown diameter (cm) per plant at different stages of growth as influenced by fertilizer levels

| Treatments                                | 14 MAP  | 16 MAP   | 18 MAP   |
|-------------------------------------------|---------|----------|----------|
| F <sub>1</sub> - Control                  | 33.66 c | 38.56 c  | 45.03 c  |
| F <sub>2</sub> - FYM alone (2.5 kg/plant) | 37.26 c | 46.23 c  | 53.04 c  |
| F <sub>3</sub> - FYM + 10:5:10*           | 37.73 c | 47.63 c  | 54.50 c  |
| F <sub>4</sub> - FYM + 15:7.5:15*         | 56.10 b | 72.07 b  | 74.50 b  |
| F <sub>5</sub> - FYM + 20:10:20*          | 72.40 a | 78.12 ab | 83.78 ab |
| F <sub>6</sub> - FYM + 25:12.5:25 *       | 73.83 a | 79.62 ab | 84.80 ab |
| F <sub>7</sub> - FYM +30:15:30*           | 80.50 a | 84.75 a  | 92.78 a  |
| Mean                                      | 55.92   | 63.86    | 69.83    |
| SEm ±                                     | 4.86    | 3.47     | 4.58     |
| LSD (P = 0.05)                            | 14.98   | 10.69    | 14.10    |

\* NPK g per plant

MAP = Months after planting

LSD applicable to Duncan's multiple range test

Means followed by same subscripts do not differ significantly

Table 10. Crown spread (m<sup>2</sup>) per plant at different stages of growth as influenced by fertilizer levels

| Treatments                                | 14 MAP   | 16 MAP   | 18 MAP  |
|-------------------------------------------|----------|----------|---------|
| F <sub>1</sub> - Control                  | 0.097 c  | 0.118 c  | 0.161 d |
| F <sub>2</sub> - FYM alone (2.5 kg/plant) | 0.101 bc | 0.178 c  | 0.238 d |
| F <sub>3</sub> - FYM + 10:5:10*           | 0.129 bc | 0.181c   | 0.240 d |
| F <sub>4</sub> - FYM + 15:7.5:15*         | 0.227 b  | 0.410 b  | 0.438 c |
| F <sub>5</sub> - FYM + 20:10:20*          | 0.412 a  | 0.479 ab | 0.551 b |
| F <sub>6</sub> - FYM + 25:12.5:25 *       | 0.431 a  | 0.560 ab | 0.565 b |
| F <sub>7</sub> - FYM +30:15:30*           | 0.511 a  | 0.562 a  | 0.679 a |
| Mean                                      | 0.272    | 0.33     | 0.410   |
| SEm +                                     | 0.043    | 0.052    | 0.0316  |
| LSD (P = 0.05)                            | 0.13     | 0.105    | 0.097   |

\* NPK g per plant

MAP = Months after planting

LSD applicable to Duncan's multiple range test

Means followed by same subscripts do not differ significantly

#### 4.1.1.7 Crown spread (m<sup>2</sup>) (Table 10)

Crown spread significantly differed due to different levels of fertilizer application at all stages of growth.

At 14 MAP, significantly higher crown spread was recorded (0.511 m<sup>2</sup>) with the application of FYM + 30:15:30 NPK g per plant which was on par with treatments F<sub>5</sub> and F<sub>6</sub>. The lowest crown spread was with control (0.097 m<sup>2</sup>) followed by FYM alone (0.101 m<sup>2</sup>) and FYM + 10:5:10 NPK g per plant (0.129 m<sup>2</sup>) which were at par but differed significantly with rest of the treatments.

At 16 MAP, FYM + 30:15:30 NPK g per plant showed highest crown spread (0.562 m<sup>2</sup>) followed by FYM + 25:12.5:25 NPK g per plant (0.560 m<sup>2</sup>) and FYM + 20:10:30 NPK g per plant (0.479 m<sup>2</sup>) which were statistically at par. The lowest was with control (0.118 m<sup>2</sup>), which was statistically on par with treatment F<sub>2</sub>, and F<sub>3</sub> but differed significantly with other treatments.

At 18 MAP, FYM + 30:15:30 NPK g per plant was showed significantly higher crown spread (0.679 m<sup>2</sup>) compared to all other treatments. The crown spread was lowest in control (0.161 m<sup>2</sup>), which was on par with the treatments F<sub>2</sub> and F<sub>3</sub>. Application of FYM + 30:15:30 NPK g per plant showed 20.2, 185.3 and 321.7 per cent increase over FYM + 25:12.5:25 NPK g per plant, FYM alone and control, respectively.

#### 4.1.1.8 Internodal length (Table 11)

Internodal length was not influenced significantly with the application of varied levels of fertilizer. However, numerically higher internodal length was observed with the combined application FYM and inorganic fertilizers than control or application of FYM alone.

Table 11. Internodal length (cm) and volume of stem (cm<sup>3</sup>) per plant at different stages of growth as influenced by fertilizer levels

| Treatments                                | Internodal length (cm) | Volume of main stem (cm <sup>3</sup> ) |
|-------------------------------------------|------------------------|----------------------------------------|
| F <sub>1</sub> - Control                  | 9.8 a                  | 338.15 b                               |
| F <sub>2</sub> - FYM alone (2.5 kg/plant) | 8.6 a                  | 442.29 b                               |
| F <sub>3</sub> - FYM + 10:5:10*           | 10.0 a                 | 500.45 b                               |
| F <sub>4</sub> - FYM + 15:7.5:15*         | 9.8 a                  | 569.52 b                               |
| F <sub>5</sub> - FYM + 20:10:20*          | 10.6 a                 | 1 270.88 ab                            |
| F <sub>6</sub> - FYM + 25:12.5:25 *       | 10.2 a                 | 1410.05 ab                             |
| F <sub>7</sub> - FYM +30:15:30*           | 10.4 a                 | 2195.31 a                              |
| Mean                                      | 9.91                   | 1009.99                                |
| SEm ±                                     | 1.43                   | 450.81                                 |
| LSD (P = 0.05)                            | NS                     | 1389.08                                |

\* NPK g per plant

MAP = Months after planting

LSD applicable to Duncan's multiple range test

Means followed by same subscripts do not differ significantly

Table 12. Dry matter production (g/ plant) and its distribution in different parts at 20 MAP as influenced by fertilizer levels

| Treatments                                | Dry weight of stem (g) | Dry weight of branches and leaves (g) | Total dry weight (g) |
|-------------------------------------------|------------------------|---------------------------------------|----------------------|
| F <sub>1</sub> - Control                  | 218.46 c               | 106.01 c                              | 324.01 c             |
| F <sub>2</sub> - FYM alone (2.5 kg/plant) | 280.26 c               | 134.48 bc                             | 414.74 c             |
| F <sub>3</sub> - FYM + 10:5:10*           | 285.46 c               | 153.59 bc                             | 439.05 c             |
| F <sub>4</sub> - FYM + 15:7.5:15*         | 429.26 b               | 217.71 b                              | 647.97 b             |
| F <sub>5</sub> - FYM + 20:10:20*          | 588.13 a               | 318.90 a                              | 907.03 a             |
| F <sub>6</sub> - FYM + 25:12.5:25 *       | 662.13 a               | 337.66 a                              | 999.79 a             |
| F <sub>7</sub> - FYM +30:15:30*           | 680.33 a               | 350.60 a                              | 1030.93 a            |
| Mean                                      | 449.15                 | 231.25                                | 680.19               |
| SEm +                                     | 41.34                  | 28.60                                 | 65.27                |
| LSD (P = 0.05)                            | 127.37                 | 88.13                                 | 201.12               |

\* NPK g per plant

MAP = Months after planting

LSD applicable to Duncan's multiple range test

Means followed by same subscripts do not differ significantly

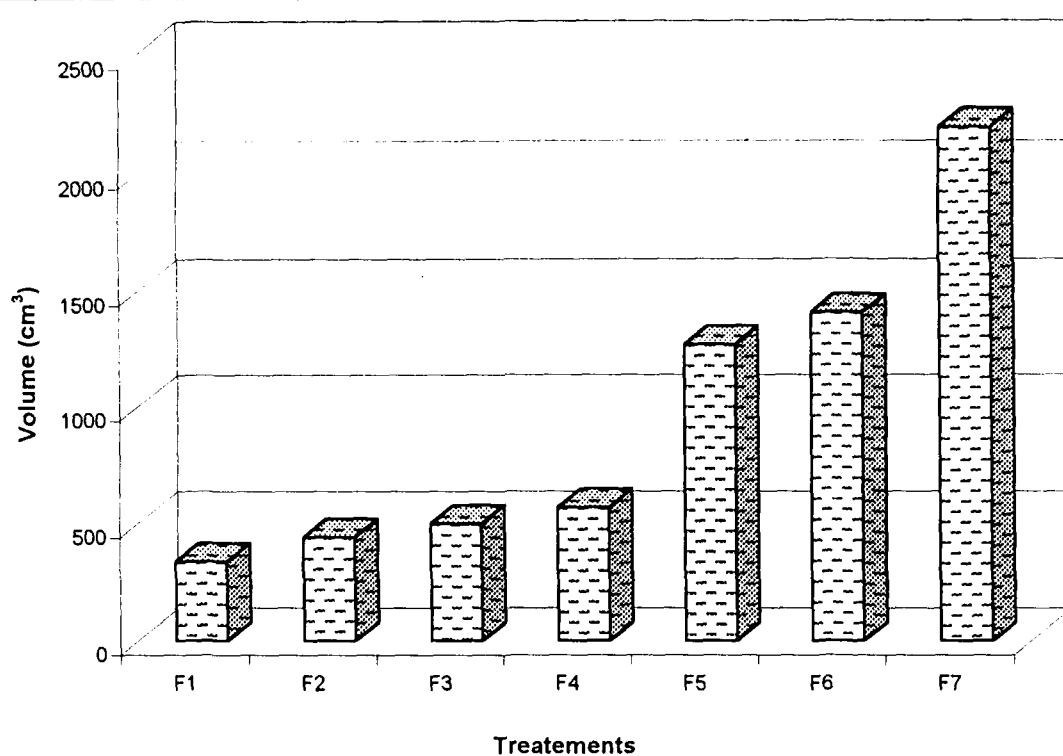


**Fig 10. Volume (cm<sup>3</sup>) of stem of the teak plants as influenced by fertilizer levels**

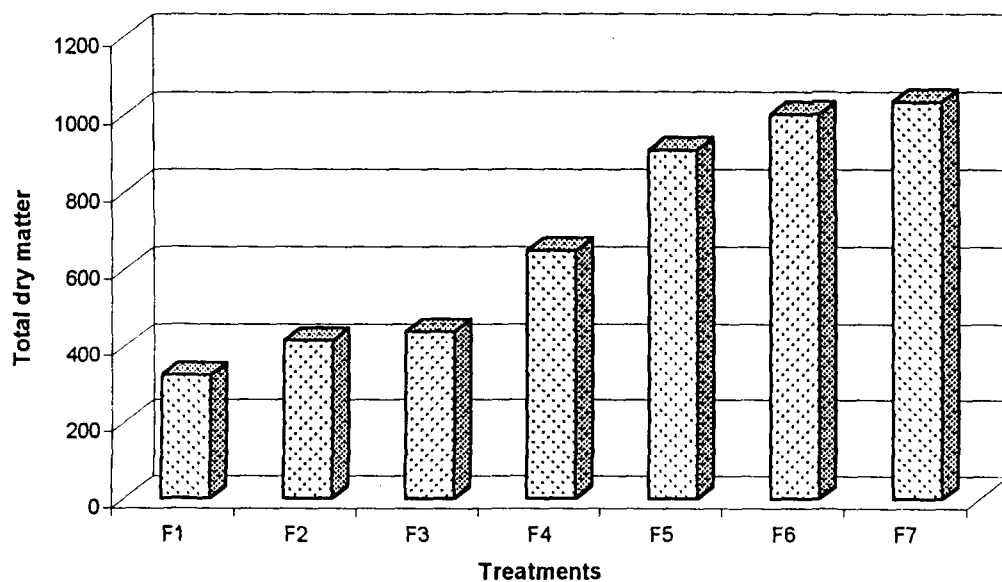


**Fig 11. Total dry matter production by teak (g/ plant) as influenced by fertilizer levels**

#### **4.1.1.9 Volume of the stem (cm<sup>3</sup>) (Table 11)**

The volume of the main stem differed significantly due to the application of different levels of fertilizer (Fig 10). Application of FYM + 30:15:30 NPK g per plant recorded significantly higher main stem volume (2195.63 cm<sup>3</sup>) which was on par with FYM + 25:12.5:25 NPK g per plant (1410.05 cm<sup>3</sup>) and FYM + 20:10:20 NPK g per plant (1270.88 cm<sup>3</sup>).

The lowest volume of main stem was noticed in control (338.15 cm<sup>3</sup>) which was on par with treatments receiving fertilizer levels of F<sub>2</sub>, F<sub>3</sub> and F<sub>4</sub>. Application of FYM + 30:15:30 NPK g per plant registered 549 and 396 per cent increase over control and FYM alone, respectively.

#### **4.1.1.10 Dry matter production (g/plant) and its distribution (Table 12)**

Dry matter production per plant and its distribution varied significantly due to the application of different levels of fertilizer.

In general, application of FYM alone or in combination with inorganic fertilizers increased total dry weight (Fig 11) and its distribution in main stem, branches and leaves. The dry matter accumulation in main stem was almost twice the dry matter accumulation in branches and leaves. On an average, the contribution of main stem biomass to the total biomass was 66 per cent. Whereas, the contribution of leaf + branches was 34 per cent

Application of FYM + 30:15:30 NPK g per plant produced the highest total dry weight per plant (1030.93 g) which was on par with F<sub>5</sub> and F<sub>6</sub> but was significantly superior to other treatments. The lowest total dry matter per plant was in control (324.01 g) followed by FYM alone (414.74 g) and FYM + 10:5:10 NPK g per plant (439.05) which were statistically on par. The per cent increase in total dry weight per plant due to application of FYM + 30:15:30 NPK g per plant

Table 13. Net increment in plant height (cm), collar diameter (cm) and number of stem nodes per plant over 8 months as influenced by fertilizer levels.

| Treatments                                | Plant height (cm) | Collar diameter (cm) | Number of nodes |
|-------------------------------------------|-------------------|----------------------|-----------------|
| F <sub>1</sub> - Control                  | 44.40 b           | 1.23 a               | 6.20 b          |
| F <sub>2</sub> - FYM alone (2.5 kg/plant) | 50.91 b           | 1.45 a               | 9.32 ab         |
| F <sub>3</sub> - FYM + 10:5:10*           | 52.28 b           | 1.69 a               | 10.22 ab        |
| F <sub>4</sub> - FYM + 15:7.5:15*         | 64.88 b           | 1.30 a               | 10.83 ab        |
| F <sub>5</sub> - FYM + 20:10:20*          | 110.00 a          | 1.82 a               | 13.67 a         |
| F <sub>6</sub> - FYM + 25:12.5:25 *       | 117.90 a          | 1.53 a               | 12.86 a         |
| F <sub>7</sub> - FYM +30:15:30*           | 120.49 a          | 1.90 a               | 11.80 a         |
| Mean                                      | 80.34             | 1.55                 | 10.71           |
| SEm +                                     | 10.13             | 0.33                 | 1.47            |
| LSD (P = 0.05)                            | 31.21             | NS                   | 4.54            |

\*NPK g per plant

MAP = Months after planting

NS = Non significant

LSD applicable to Duncan's multiple range test

Means followed by same subscripts do not differ significantly

was 218.2, 148.6 and 3.1 per cent over control, FYM alone and FYM + 25:12.5:25 NPK g per plant, respectively.

Similar trend was observed in dry matter distribution in different parts (main stem and branches and leaves) due to application of different levels of fertilizer.

#### **4.1.2 Growth increment of teak (Table 13)**

Data on net increment in growth parameters of teak viz., plant height, collar diameter and number of stem nodes per plant over 8 months period are presented in this section.

##### **4.1.2.1 Net increment in plant height (cm)**

Increment in plant height over 8 months varied significantly due to different levels of fertilizer application. Net increment in plant height was significantly higher with FYM + 30:15:30 NPK g per plant (120.49 cm) which was on par with FYM + 25:12.5:25 NPK g per plant (117.90 cm) and FYM + 20:10:20 NPK g per plant. The extent of increase with FYM + 30:15:30 NPK g per plant was 171.37 and 136.25 per cent over control and application of FYM alone, respectively. The lowest height increment was in control (44.4 cm) which was statistically on par with  $F_2$ ,  $F_3$  and  $F_4$ .

##### **4.1.2.2 Net increment in collar diameter (cm)**

Increment in the collar diameter of plant over 8 months of study did not differ significantly due to different fertilizer levels. However, the highest increment in the collar diameter was recorded with FYM + 30:15:30 NPK g per plant (1.90 cm).

Table 14. Form factor and fertilizer use efficiency (FUE) of teak plants as influenced by fertilizer levels.

| Treatments                                | Form factor | Fertilizer use efficiency (%) |
|-------------------------------------------|-------------|-------------------------------|
| F <sub>1</sub> - Control                  | 0.69 a      | —                             |
| F <sub>2</sub> - FYM alone (2.5 kg/plant) | 0.69 a      | 29.9 b                        |
| F <sub>3</sub> - FYM + 10:5:10*           | 0.65 ab     | 36.8 b                        |
| F <sub>4</sub> - FYM + 15:7.5:15*         | 0.67 ab     | 100.2 b                       |
| F <sub>5</sub> - FYM + 20:10:20*          | 0.58 b      | 179.9 a                       |
| F <sub>6</sub> - FYM + 25:12.5:25 *       | 0.58 b      | 209.5 a                       |
| F <sub>7</sub> - FYM +30:15:30*           | 0.59 b      | 217.7 a                       |
| Mean                                      | 0.62        | 110.6                         |
| SEm +                                     | 0.03        | 33.31                         |
| LSD (P = 0.05)                            | 0.10        | 104.96                        |

\* NPK g per plant

MAP = Months after planting

LSD applicable to Duncan's multiple range test

Means followed by same subscripts do not differ significantly

#### **4.1.2.3 Net increment in number of main stem nodes per plant**

There was significant difference in the increment of number of stem nodes per plant over 8 months period. Net increment in stem nodes per plant was significantly higher with FYM + 20:10:20 NPK g per plant (13.67) which was statistically on par with all other treatments except control (6.20). The extent of increase in number of stem nodes per plant with the application of FYM + 20:10:20 NPK g per plant was 120.4 and 46.7 per cent over control and application of FYM alone, respectively.

#### **4.1.3 Other parameters**

##### **4.1.3.1 Form factor (Table 14)**

Form factor differed significantly with the application of fertilizer at different levels. In general, higher levels of inorganic fertilizers decreased the form factor. Higher form factor was noticed in control (0.69) and FYM alone (0.69) which were on par with the treatments  $F_3$  and  $F_4$  but significantly superior to rest of the treatments. The form factor was lowest with FYM + 20:10:20 NPK g per plant (0.58) and FYM + 25:12.5:25 NPK g per plant (0.58) followed by FYM + 30:15:30 NPK g per plant (0.59) which were at par.

##### **4.1.3.2 Fertilizer use efficiency (%) (Table 14)**

FUE was highest with FYM + 30:15:30 NPK g per plant (217.68%) followed by  $F_6$  (209.5 %) and  $F_5$  (179.9 %) which were at par but differed significantly with rest of the treatments.

##### **4.1.3.3 Uptake of nutrients (g/plant) by teak leaves and stem (Table 15)**

Nutrient uptake (N, P and K) by the teak varied significantly due to different fertilizer levels. In general, nutrient content (N, P and K) in stem was

Table 15. Uptake of N, P and K by teak (g/ plant) as influenced by fertilizer levels

| Treatments                               | Nitrogen uptake (g/plant) |        |          | Phosphorus uptake(g/plant) |        |         | Potassium uptake (g/plant) |        |         |
|------------------------------------------|---------------------------|--------|----------|----------------------------|--------|---------|----------------------------|--------|---------|
|                                          | Leaves                    | Stem   | Total    | Leaves                     | Stem   | Total   | Leaves                     | Stem   | Total   |
| F <sub>1</sub> - Control                 | 0.61 d                    | 1.26 d | 1.87 e   | 0.11 b                     | 0.45 d | 0.56 f  | 0.71 d                     | 1.78 d | 2.49 e  |
| F <sub>2</sub> - Only FYM (2.5 kg/plant) | 1.20 d                    | 1.93 d | 3.13 de  | 0.19 b                     | 0.75 d | 0.94 ef | 0.92 d                     | 2.45 d | 3.37 d  |
| F <sub>3</sub> - FYM + 10:5:10*          | 1.43 cd                   | 2.39 d | 3.82 d   | 0.23 b                     | 0.90 d | 1.13 e  | 1.23 cd                    | 2.70 d | 3.93 d  |
| F <sub>4</sub> - FYM + 15:7.5:15*        | 2.41 c                    | 3.82 c | 6.23 c   | 0.40 ab                    | 1.41 c | 1.81 d  | 1.81 c                     | 4.89 c | 9.67 bc |
| F <sub>5</sub> - FYM + 20:10:20*         | 4.00 b                    | 5.94 b | 9.94 b   | 0.73 ab                    | 2.40 b | 3.13 c  | 3.10 b                     | 7.09 b | 10.19 b |
| F <sub>6</sub> - FYM + 25:12.5:25*       | 4.81 ab                   | 8.54 a | 13.35 ab | 0.86 ab                    | 3.12 a | 3.94 b  | 3.62 ab                    | 8.89 a | 12.51 a |
| F <sub>7</sub> - FYM +30:15:30*          | 5.81 a                    | 9.00 a | 14.81a   | 1.06 a                     | 3.53 a | 4.59 a  | 4.34 a                     | 9.49 a | 13.83 a |
| Mean                                     | 2.89                      | 4.65   | 7.53     | 0.58                       | 1.80   | 2.42    | 2.23                       | 5.34   | 7.59    |
| Sem±                                     | 0.35                      | 0.40   | 0.57     | 0.08                       | 0.16   | 0.18    | 0.27                       | 0.58   | 0.53    |
| LSD (P = 0.05)                           | 1.101                     | 1.22   | 1.76     | 0.23                       | 0.48   | 0.55    | 0.84                       | 1.78   | 1.63    |

\*NPK g per plant

Means followed by same subscripts do not differ significantly

higher than in leaves. Total uptake of N, P and K ranged from 1.87 to 14.81, 0.5 to 4.59 and 2.49 to 13.83 g per plant, respectively.

Application of FYM + 30:15:30 NPK g per plant significantly increased the total N (14.81g/plant) compared to all other treatments except F6 (13.35 g/ plant). Increase in total uptake of N was to the tune of 692, 373 and 11 per cent over control, FYM alone and FYM + 25:12.5:25 NPK g per plant, respectively. Similar trend in nitrogen content (g/ plant) in plant parts viz., leaves and stem was observed due to the application of fertilizers at various levels.

Phosphorus uptake was significantly higher (4.59 g/ plant) with the application FYM + 30:15:30 NPK g per plant than rest of the treatments. Lowest uptake was in control (0.56 g/ plant) followed by FYM alone (0.94 g/ plant). The increase in P uptake due to application of FYM + 30:15:30 NPK g per plant was 720, 388 and 17 per cent over control, FYM alone and FYM + 25:12.5:25 NPK g per plant, respectively. Similar trend in effect of fertilizer levels on phosphorus content (g/ plant) in leaves and stem was noticed.

Total uptake of potassium was highest (13.83 g/ plant) with the application of FYM + 30:15:30 NPK g per plant followed by FYM + 25:12.5:25 NPK g per plant (12.51 g/plant) which were at par but differed significantly with other treatments. The lowest K uptake was noticed in control. The increase in total uptake of K was 11, 310 and 455 per cent over FYM + 25:12.5:25 NPK g per plant, FYM alone and control, respectively. Similar trend in K content (g/ plant) in leaves and stem due to different fertilizer levels was observed.

Table 16. Plant height of paddy (cm) at different growth stages as influenced by distance from teak row and fertilizer levels imposed on associated teak.

| Treatments                                | 60 DAS   | 120 DAS   | At harvest |
|-------------------------------------------|----------|-----------|------------|
| Distance from teak row                    |          |           |            |
| D <sub>1</sub> - 0 to 2 m                 | 50.93 a  | 85.65 a   | 86.41 a    |
| D <sub>2</sub> - 2 to 4 m                 | 52.08 a  | 86.73 b   | 87.10 b    |
| Sem +                                     | 0.398    | 0.224     | 0.206      |
| LSD (P = 0.05)                            | NS       | 0.675     | 0.623      |
| Fertilizer levels                         |          |           |            |
| F <sub>1</sub> - Control                  | 51.57 a  | 85.00 bc  | 86.93 a    |
| F <sub>2</sub> - FYM alone (2.5 kg/plant) | 51.49 a  | 87.98 a   | 87.51 a    |
| F <sub>3</sub> - FYM + 10:5:10*           | 51.47 a  | 87.03 ab  | 87.43 a    |
| F <sub>4</sub> - FYM + 15:7.5:15*         | 50.69 a  | 85.90 a-c | 87.25 a    |
| F <sub>5</sub> - FYM + 20:10:20*          | 52.71 a  | 87.33 ab  | 87.22 a    |
| F <sub>6</sub> - FYM + 25:12.5:25 *       | 51.11 a  | 85.63 a-c | 87.29 a    |
| F <sub>7</sub> - FYM +30:15:30*           | 51.25 a  | 86.63 ab  | 86.63 a    |
| Sem +                                     | 0.710    | 0.703     | 0.473      |
| LSD (P = 0.05)                            | NS       | 2.165     | NS         |
| Interactions                              |          |           |            |
| D <sub>1</sub> x F <sub>1</sub>           | 51.06 b  | 84.28 e   | 86.79 a-c  |
| D <sub>1</sub> x F <sub>2</sub>           | 51.69 ab | 88.05 a   | 88.21 a    |
| D <sub>1</sub> x F <sub>3</sub>           | 51.13 ab | 86.52 a-d | 87.16 a-c  |
| D <sub>1</sub> x F <sub>4</sub>           | 49.96 b  | 85.38 c-e | 86.65 a-c  |
| D <sub>1</sub> x F <sub>5</sub>           | 51.11 ab | 87.53 a-c | 86.94 a-c  |
| D <sub>1</sub> x F <sub>6</sub>           | 50.31 b  | 83.92 eg  | 86.89 a-c  |
| D <sub>1</sub> x F <sub>7</sub>           | 51.23 ab | 85.88 b-e | 86.01 c    |
| D <sub>2</sub> x F <sub>1</sub>           | 52.08 ab | 85.73 b-e | 87.03 a-c  |
| D <sub>2</sub> x F <sub>2</sub>           | 51.29 ab | 87.91 ab  | 86.80 a-c  |
| D <sub>2</sub> x F <sub>3</sub>           | 51.81 ab | 87.48 a-d | 87.70 ab   |
| D <sub>2</sub> x F <sub>4</sub>           | 51.42 ab | 86.56 a-d | 87.85 ab   |
| D <sub>2</sub> x F <sub>5</sub>           | 54.32 a  | 87.14 a-d | 87.50 a-c  |
| D <sub>2</sub> x F <sub>6</sub>           | 51.91 ab | 87.35 a-c | 87.51 a-c  |
| D <sub>2</sub> x F <sub>7</sub>           | 51.27 ab | 86.93 a-d | 87.17 a-c  |
| Sem +                                     | 1.053    | 0.591     | 0.545      |
| LSD (P = 0.05)                            | 3.194    | 1.794     | 1.654      |

\* NPK g per plant

MAP = Months after planting

LSD applicable to Duncan's multiple range test

Means followed by same subscripts do not differ significantly

## 4.2 Tree – Crop interaction

### 4.2.1 Effect of teak on growth, yield and other parameters related to paddy

Paddy crop was grown in area adjacent to teak row. In order to assess effect of teak on associated paddy, observations on paddy were recorded at three stages i. e. 60, 120 days after sowing (DAS) and at harvest.

#### 4.2.1.1 Plant height (cm) (Table 16)

Distance from teak row significantly influenced the plant height of paddy at 120 DAS and at harvest. At both the stages, plant height of paddy was significantly lower at 0 – 2 m distance (85.65 and 86.41 cm, respectively) than at 2 to 4 m distance (86.73 and 87.1 cm, respectively).

Application of different levels of fertilizer to teak plants significantly affected the plant height of associated paddy crop at 120 DAS; where as, the differences were non significant at 60 DAS and at harvest except interaction effects. At 60 DAS, among the interactions, the combination of  $D_2 \times F_5$  (54.32 cm) showed significantly higher plant height of paddy which was on par with the rest of the combinations except  $D_1 \times F_4$  (49.96 cm),  $D_1 \times F_1$  (51.06 cm) and  $D_1 \times F_6$  (50.31 cm).

At 120 DAS, significantly higher plant height was recorded with only FYM (87.98 cm) which was statistically on par with other treatments except control. The combination of  $D_1 \times F_2$  (88.05 cm) recorded significantly higher plant height and lowest was with  $D_1 \times F_6$  (81.92 cm).

At harvest, among interaction between distance from teak row and fertilizer levels imposed on teak significantly influenced the plant height of associated paddy. The highest plant height was noticed with the combination of

Table 17. Dry weight per plant (g) at different growth stages as influenced by distance from teak row and fertilizer levels imposed on associated teak.

| Treatments                                | 60 DAS   | 120 DAS   | At harvest |
|-------------------------------------------|----------|-----------|------------|
| Distance from teak row                    |          |           |            |
| D <sub>1</sub> - 0 to 2 m                 | 6.06 a   | 19.16 a   | 19.20 a    |
| D <sub>2</sub> - 2 to 4 m                 | 5.91 a   | 19.59 a   | 19.72 a    |
| Sem +                                     | 0.09     | 0.18      | 0.12       |
| LSD (P = 0.05)                            | NS       | NS        | NS         |
| Fertilizer levels                         |          |           |            |
| F <sub>1</sub> - Control                  | 7.11 a   | 19.79 a   | 19.66 ab   |
| F <sub>2</sub> - FYM alone (2.5 kg/plant) | 6.29 a-c | 19.49 a   | 19.88 ab   |
| F <sub>3</sub> - FYM + 10:5:10*           | 6.69 ab  | 20.59 a   | 20.85 a    |
| F <sub>4</sub> - FYM + 15:7.5:15*         | 4.90 c   | 20.59 a   | 20.62 a    |
| F <sub>5</sub> - FYM + 20:10:20*          | 5.79 bc  | 18.61 a   | 19.22 ab   |
| F <sub>6</sub> - FYM + 25:12.5:25*        | 5.37 c   | 18.45 a   | 18.08 b    |
| F <sub>7</sub> - FYM +30:15:30*           | 5.94 bc  | 18.10 a   | 17.90 b    |
| Sem +                                     | 0.354    | 0.861     | 0.762      |
| LSD (P = 0.05)                            | 1.092    | NS        | 2.348      |
| Interactions                              |          |           |            |
| D <sub>1</sub> x F <sub>1</sub>           | 7.21a    | 19.84 ab  | 19.51 c-e  |
| D <sub>1</sub> x F <sub>2</sub>           | 6.48 a-d | 19.32 ab  | 19.57 c-e  |
| D <sub>1</sub> x F <sub>3</sub>           | 6.92 ab  | 20.65 a   | 20.59 ab   |
| D <sub>1</sub> x F <sub>4</sub>           | 4.88 f   | 20.68 a   | 20.58 ab   |
| D <sub>1</sub> x F <sub>5</sub>           | 6.00 c-e | 18.57 b-d | 19.20 df   |
| D <sub>1</sub> x F <sub>6</sub>           | 5.45 ef  | 17.36 d   | 17.79 gh   |
| D <sub>1</sub> x F <sub>7</sub>           | 5.53 ef  | 17.66 cd  | 17.36 h    |
| D <sub>2</sub> x F <sub>1</sub>           | 7.00 a   | 19.73 ab  | 20.13 a-d  |
| D <sub>2</sub> x F <sub>2</sub>           | 6.00 c-e | 19.66 ab  | 19.76 b-d  |
| D <sub>2</sub> x F <sub>3</sub>           | 6.64 a-c | 20.53 a   | 21.01 a    |
| D <sub>2</sub> x F <sub>4</sub>           | 4.93 f   | 20.50 a   | 20.65 ab   |
| D <sub>2</sub> x F <sub>5</sub>           | 5.59 ef  | 18.64 b-d | 19.23 d-f  |
| D <sub>2</sub> x F <sub>6</sub>           | 5.29 ef  | 19.54 ab  | 18.37 fg   |
| D <sub>2</sub> x F <sub>7</sub>           | 6.35 b-e | 18.53 b-d | 18.80 ef   |
| Sem +                                     | 0.25     | 0.47      | 0.295      |
| LSD (P = 0.05)                            | 0.757    | 1.42      | 0.896      |

\* NPK g per plant

MAP = Months after planting

LSD applicable to Duncan's multiple range test

Means followed by same subscripts do not differ significantly

$D_1 \times F_2$  (88.21 cm) which was on par with all other combinations except  $D_1 \times F_6$ ,  $D_1 \times F_7$  and  $D_2 \times F_6$ .

#### 4.2.1.2 Dry weight per plant (g) (Table 17)

Dry weight of paddy did not differ significantly due to distance from the teak row at all stages of growth.

Fertilizer levels imposed on teak plants showed significant influence on dry weight per plant of associated paddy at 60 DAS and at harvest. At 60 DAS, dry weight was maximum in control (7.1g) followed by FYM alone (6.19 g) and FYM + 10: 5: 10 NPK g per plant (6.69 g) which were at par but significantly superior to other treatments. Among Interactions, combinations of  $D_1 \times F_1$  (7.21 g) recorded highest dry weight per plant followed by  $D_2 \times F_1$  (7.00 g),  $D_1 \times F_3$  (6.92 g) and  $D_1 \times F_2$  (6.48 g) which were at par but recorded significantly higher dry weight compare to all other combinations.

At 120 DAS, dry weight per plant was not significantly influenced due to the application of fertilizer levels. However, combinations of  $D_1 \times F_4$  recorded highest dry weight per plant (20.68) followed by  $D_1 \times F_3$  (20.65 g),  $D_2 \times F_3$  (20.53 g) and  $D_2 \times F_4$  (20.50 g) which were at par but significantly superior to other combinations.

At harvest, dry weight per plant was maximum with FYM + 10: 5: 10 NPK g per plant (20.85 g) followed by FYM + 15: 12.5: 15 NPK g per plant (20.62 g) which were at par with  $F_1$ ,  $F_2$  and  $F_5$  but significantly superior to other treatments.

In the interaction, combination of  $D_2 \times F_3$  (21.01 g) showed maximum dry weight per plant compared to all other combinations which were at par but significantly higher followed by  $D_2 \times F_4$  (20.65 g),  $D_1 \times F_4$  (20.58 g) and  $D_1 \times F_3$

Table 18. Number of tillers per meter length of row at different stages of growth as influenced by distance from teak row and fertilizer levels imposed on associated teak.

| Treatments                                | 60 DAS   | 120 DAS   | At harvest |
|-------------------------------------------|----------|-----------|------------|
| Distance from teak row                    |          |           |            |
| D <sub>1</sub> - 0 to 2 m                 | 81.81 a  | 85.09 a   | 85.95 a    |
| D <sub>2</sub> - 2 to 4 m                 | 83.09 a  | 87.29 b   | 87.95 b    |
| Sem +                                     | 0.4726   | 0.6033    | 0.480      |
| LSD (P = 0.05)                            | NS       | 1.824     | 1.462      |
| Fertilizer levels                         |          |           |            |
| F <sub>1</sub> - Control                  | 84.17 a  | 86.00 ab  | 87.83 ab   |
| F <sub>2</sub> - FYM alone (2.5 kg/plant) | 82.50 ab | 91.33 a   | 90.67 a    |
| F <sub>3</sub> - FYM + 10:5:10*           | 82.33 ab | 85.50 b   | 87.17 b    |
| F <sub>4</sub> - FYM + 15:7.5:15*         | 83.67 a  | 87.83 ab  | 86.17 b    |
| F <sub>5</sub> - FYM + 20:10:20*          | 82.33 ab | 84.50 b   | 84.83 b    |
| F <sub>6</sub> - FYM + 25:12.5:25*        | 82.50 ab | 86.00 ab  | 86.67 b    |
| F <sub>7</sub> - FYM +30:15:30*           | 79.67 b  | 82.17 b   | 85.33 b    |
| Sem +                                     | 0.906    | 1.833     | 1.13       |
| LSD (P = 0.05)                            | 2.791    | 5.647     | 3.48       |
| Interactions                              |          |           |            |
| D <sub>1</sub> x F <sub>1</sub>           | 84.33 a  | 86.67 b-d | 87.33 bc   |
| D <sub>1</sub> x F <sub>2</sub>           | 82.00 ab | 90.00 ab  | 89.33 ab   |
| D <sub>1</sub> x F <sub>3</sub>           | 83.33 a  | 86.00 b-d | 87.67 bc   |
| D <sub>1</sub> x F <sub>4</sub>           | 83.00 ab | 86.00 b-d | 86.33 b-d  |
| D <sub>1</sub> x F <sub>5</sub>           | 80.33 ab | 83.67 de  | 83.00 d    |
| D <sub>1</sub> x F <sub>6</sub>           | 81.00 ab | 83.33 de  | 84.67 cd   |
| D <sub>1</sub> x F <sub>7</sub>           | 78.67 b  | 80.00 e   | 83.33 d    |
| D <sub>2</sub> x F <sub>1</sub>           | 84.00 a  | 85.33 b-e | 88.33 a-c  |
| D <sub>2</sub> x F <sub>2</sub>           | 83.00 ab | 92.67 a   | 92.00 a    |
| D <sub>2</sub> x F <sub>3</sub>           | 81.33 ab | 85.00 b-e | 86.67 b-d  |
| D <sub>2</sub> x F <sub>4</sub>           | 84.33 ab | 89.67 a-c | 86.00 b-d  |
| D <sub>2</sub> x F <sub>5</sub>           | 84.33 a  | 85.33 b-e | 86.67 b-d  |
| D <sub>2</sub> x F <sub>6</sub>           | 84.00 a  | 88.67 a-d | 88.67 ab   |
| D <sub>2</sub> x F <sub>7</sub>           | 80.67 ab | 84.33 c-e | 87.33 bc   |
| Sem +                                     | 1.25     | 1.596     | 1.272      |
| LSD (P = 0.05)                            | 3.792    | 4.841     | 3.859      |

\* NPK g per plant

MAP = Months after planting

LSD applicable to Duncan's multiple range test

Means followed by same subscripts do not differ significantly

(20.59 g). The lowest was recorded with  $D_1 \times F_7$  (17.36 g) which was on par with  $D_1 \times F_6$  (17.79 g).

#### 4.2.2.3 Number of tillers per meter row length of paddy (Table 18)

There was no significant difference in number of tillers per meter due to distance from teak row at 60 DAS. Where as, at 120 DAS and at harvest stage number of tillers differed significantly. At both these stages number of tillers were significantly higher at 2 to 4 distance (87.29 and 87.95, respectively) compared to 0 to 2 m distance (85.09 and 85.95, respectively).

Application of fertilizer levels and its combination with distance from teak row significantly influenced number of tiller per meter row length of paddy at all the stages.

At 60 DAS, the maximum number of tillers per meter row length of paddy was recorded with control (84.17) which was on par with rest of the treatments except FYM + 30:15:30 NPK g per plant. Among the interactions, maximum number of tillers per meter was noticed in the combinations of  $D_1 \times F_1$ ,  $D_2 \times F_4$  and  $D_2 \times F_5$  (84.33), which were at par with other combinations except  $D_1 \times F_7$  (78.67).

At 120 DAS, application of FYM alone showed significantly more number of tillers (91.33) compared to  $F_3$ ,  $F_5$  and  $F_7$  but was on par with rest of the treatments. With regards to interaction effect, combination of  $D_2 \times F_2$  showed highest number of tillers per meter length (92.67) followed by  $D_1 \times F_2$  (90.0) which were at par but significantly superior to other combinations except  $D_2 \times F_4$  and  $D_2 \times F_7$ . The lowest number of tillers was recorded in  $D_1 \times F_7$  (80.0).

At harvest, number of tillers was significantly influenced due to fertilizer levels. Application of FYM alone showed significantly more number of tiller (90.67) than other levels of fertilizer except control ( $F_1$ ). Among interaction

Table 19. Panicle length (cm) and thousand grain weight of paddy as influenced by distance from teak row and fertilizer levels imposed on associated teak.

| Treatments                                | Panicle length (cm) |            | 1000Grain weight (gm) |
|-------------------------------------------|---------------------|------------|-----------------------|
|                                           | 120 DAS             | At harvest |                       |
| Distance from teak row                    |                     |            |                       |
| D <sub>1</sub> - 0 to 2 m                 | 15.76 a             | 16.45 a    | 21.60 a               |
| D <sub>2</sub> - 2 to 4 m                 | 15.99 a             | 17.03 a    | 22.22 a               |
| Sem +                                     | 0.195               | 0.228      | 0.345                 |
| LSD (P = 0.05)                            | NS                  | NS         | NS                    |
| Fertilizer levels                         |                     |            |                       |
| F <sub>1</sub> - Control                  | 15.66 a             | 16.44 a    | 21.97 a               |
| F <sub>2</sub> - FYM alone (2.5 kg/plant) | 15.59 a             | 17.08 a    | 22.35 a               |
| F <sub>3</sub> - FYM + 10:5:10*           | 16.37 a             | 16.50 a    | 22.84 a               |
| F <sub>4</sub> - FYM + 15:7.5:15*         | 15.69 a             | 16.51 a    | 21.75 a               |
| F <sub>5</sub> - FYM + 20:10:20*          | 16.24 a             | 16.87 a    | 21.63 a               |
| F <sub>6</sub> - FYM + 25:12.5:25*        | 16.04 a             | 17.03 a    | 21.46 a               |
| F <sub>7</sub> - FYM +30:15:30*           | 15.57 a             | 16.79 a    | 21.33 a               |
| Sem +                                     | 0.275               | 0.285      | 0.5647                |
| LSD (P = 0.05)                            | NS                  | NS         | NS                    |
| Interactions                              |                     |            |                       |
| D <sub>1</sub> x F <sub>1</sub>           | 15.14 a             | 16.40 ab   | 22.09 a               |
| D <sub>1</sub> x F <sub>2</sub>           | 15.50 a             | 16.92 ab   | 21.71 a               |
| D <sub>1</sub> x F <sub>3</sub>           | 16.37 a             | 16.04 b    | 22.88 a               |
| D <sub>1</sub> x F <sub>4</sub>           | 15.42 a             | 16.01 b    | 21.73 a               |
| D <sub>1</sub> x F <sub>5</sub>           | 16.32 a             | 16.68 ab   | 21.77 a               |
| D <sub>1</sub> x F <sub>6</sub>           | 16.47 a             | 16.78 ab   | 20.40 a               |
| D <sub>1</sub> x F <sub>7</sub>           | 15.11 a             | 16.36 a    | 21.71 a               |
| D <sub>2</sub> x F <sub>1</sub>           | 16.18 a             | 16.49 a    | 21.86 a               |
| D <sub>2</sub> x F <sub>2</sub>           | 15.68 a             | 17.23 a    | 22.99 a               |
| D <sub>2</sub> x F <sub>3</sub>           | 16.37 a             | 16.96 ab   | 22.80 a               |
| D <sub>2</sub> x F <sub>4</sub>           | 15.96 a             | 17.00 ab   | 21.76 a               |
| D <sub>2</sub> x F <sub>5</sub>           | 16.16 a             | 17.06 ab   | 21.49 a               |
| D <sub>2</sub> x F <sub>6</sub>           | 15.60 a             | 17.28 a    | 22.53 a               |
| D <sub>2</sub> x F <sub>7</sub>           | 16.03 a             | 17.22 a    | 22.99 a               |
| Sem +                                     | 0.518               | 0.339      | 0.915                 |
| LSD (P = 0.05)                            | NS                  | 1.17       | NS                    |

\* NPK g per plant

MAP = Months after planting

LSD applicable to Duncan's multiple range test

Means followed by same subscripts do not differ significantly

between distance from teak row and fertilizer levels, maximum number of tillers were noticed in the combination of  $D_2 \times F_2$  (92.00) which was followed by  $D_1 \times F_2$  (89.33),  $D_2 \times F_1$  (88.33) and  $D_2 \times F_6$  (88.67) which were at par but significantly superior to rest of the combinations.

#### **4.2.1.4 Panicle length (cm) (Table 19)**

There was no significant difference in the panicle length of paddy to its distance from teak row and fertilizer levels at 120 DAS and at harvest stage. However, at harvest, higher (17.03 cm) panicle length was recorded at 2 to 4 m distance compared to 0 to 2 m distance from the teak row. And, application of FYM alone registered numerically higher panicle length (17.08 cm).

Among the interactions between distance from teak row and fertilizer levels applied to associated teak, there was significant variation in panicle length of paddy only at harvest. The combination of  $D_2 \times F_6$  resulted in maximum panicle length (17.28 cm) which was statistically on par with all other combinations except with  $D_1 \times F_4$  (16.01 cm) and  $D_1 \times F_3$  (16.04 cm).

#### **4.2.1.5 Thousand grain weight (g) (Table 19)**

There was no significant difference in 1000 grain weight of paddy due to distance from teak row, fertilizer levels and their interactions.

#### **4.2.1.6 Grain yield (kg/ ha) (Table 20)**

The grain yield of paddy did not differ significantly with respect to its distance from teak row (Fig 12).

Fertilizer levels imposed on teak showed a significant difference in grain yield of associated paddy. The maximum yield (1364 kg/ha) was observed with FYM alone application, which was on par with treatments  $F_1$ ,  $F_3$  and  $F_4$ .

Table 20. Grain yield (kg/ha) and straw yield (kg/ha) of paddy as influenced by distance from teak row and fertilizer levels imposed on associated teak.

| Treatments                                | Grain yield<br>(kg/ha) | Straw yield<br>(kg/ha) |
|-------------------------------------------|------------------------|------------------------|
| Distance from teak row                    |                        |                        |
| D <sub>1</sub> - 0 to 2 m                 | 1335 a                 | 3661 a                 |
| D <sub>2</sub> - 2 to 4 m                 | 1348 a                 | 3695 a                 |
| Sem ±                                     | 5.04                   | 16.45                  |
| LSD                                       | NS                     | NS                     |
| Fertilizer levels                         |                        |                        |
| F <sub>1</sub> - Control                  | 1342 a-c               | 3678 b                 |
| F <sub>2</sub> - FYM alone (2.5 kg/plant) | 1364 a                 | 3683 b                 |
| F <sub>3</sub> - FYM + 10:5:10*           | 1356 ab                | 3775 a                 |
| F <sub>4</sub> - FYM + 15:7.5:15*         | 1344 a-c               | 3687 b                 |
| F <sub>5</sub> - FYM + 20:10:20*          | 1337 b-d               | 3630 b                 |
| F <sub>6</sub> - FYM + 25:12.5:25*        | 1331 cd                | 3669 b                 |
| F <sub>7</sub> - FYM +30:15:30*           | 1315 d                 | 3626 b                 |
| Sem ±                                     | 7.39                   | 22.38                  |
| LSD (P = 0.05)                            | 22.76                  | 68.97                  |
| Interactions                              |                        |                        |
| D <sub>1</sub> x F <sub>1</sub>           | 1338 a-d               | 3667 ab                |
| D <sub>1</sub> x F <sub>2</sub>           | 1349 a-d               | 3735 ab                |
| D <sub>1</sub> x F <sub>3</sub>           | 1351 a-d               | 3747 ab                |
| D <sub>1</sub> x F <sub>4</sub>           | 1321 b-d               | 3642 b                 |
| D <sub>1</sub> x F <sub>5</sub>           | 1330 b-d               | 3629 b                 |
| D <sub>1</sub> x F <sub>6</sub>           | 1316 cd                | 3624 b                 |
| D <sub>1</sub> x F <sub>7</sub>           | 1309 d                 | 3604 b                 |
| D <sub>2</sub> x F <sub>1</sub>           | 1346 a-d               | 3690 ab                |
| D <sub>2</sub> x F <sub>2</sub>           | 1379 a                 | 3630 b                 |
| D <sub>2</sub> x F <sub>3</sub>           | 1361 a-c               | 3802 a                 |
| D <sub>2</sub> x F <sub>4</sub>           | 1367 ab                | 3750 ab                |
| D <sub>2</sub> x F <sub>5</sub>           | 1345 a-d               | 3632 b                 |
| D <sub>2</sub> x F <sub>6</sub>           | 1346 a-d               | 3715 ab                |
| D <sub>2</sub> x F <sub>7</sub>           | 1322b-d                | 3648 b                 |
| Sem ±                                     | 13.3                   | 43.5                   |
| LSD (P = 0.05)                            | 40.4                   | 135.6                  |

\* NPK g per plant

MAP = Months after planting

LSD applicable to Duncan's multiple range test

Means followed by same subscripts do not differ significantly

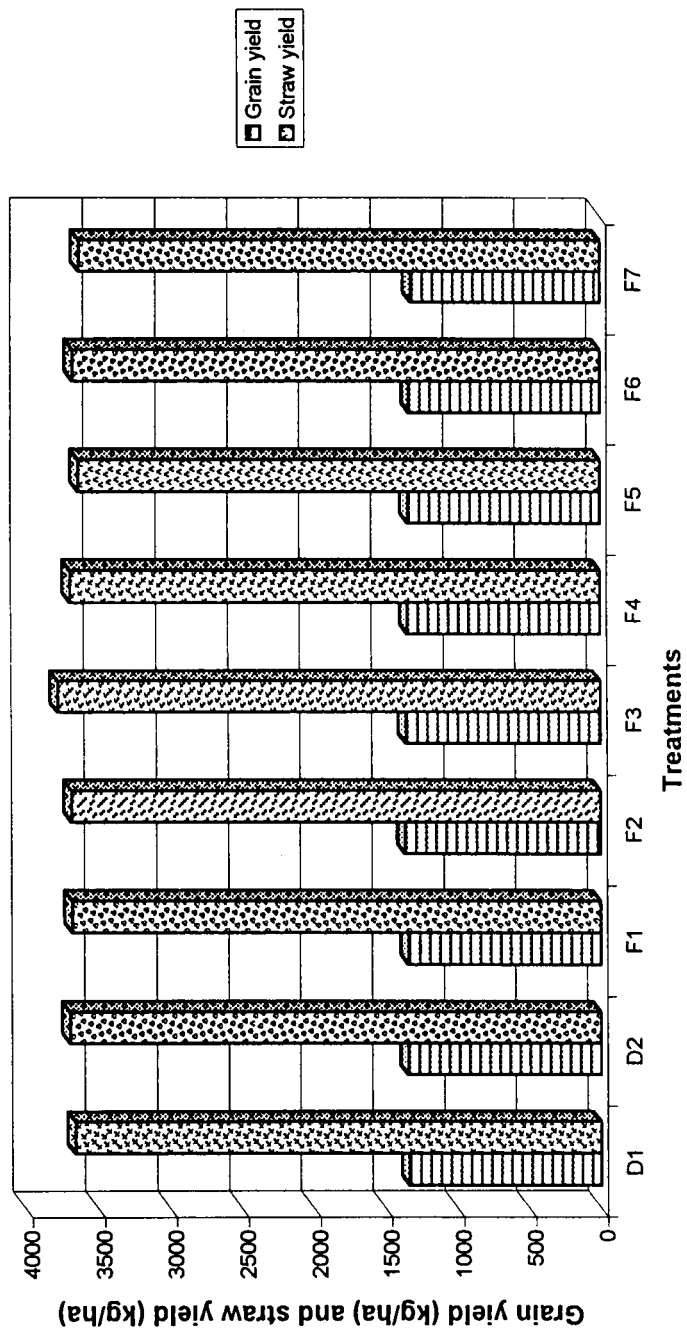


Fig 12. Grain yield (kg/ha) and straw yield (kg/ha) of paddy as influenced by distance from teak row and fertilizer levels imposed on teak.

Application of FYM + 30:15:30 NPK g per plant recorded 3.71 per cent decrease in the grain yield compare to application of FYM alone.

Grain yield of paddy was significantly influenced by interaction between distance from teak row and fertilizer levels. The grain yield was significantly higher in  $D_2 \times F_2$  (1379 kg/ha) which was statistically on par with rest of the treatments except  $D_1 \times F_4$ ,  $D_1 \times F_5$ ,  $D_1 \times F_6$ ,  $D_1 \times F_7$  and  $D_2 \times F_7$ . Lowest grain yield was recorded at  $D_1 \times F_7$  (1309 kg/ha).

#### **4.2.1.7 Straw yield (kg/ha) (Table 20)**

No significant difference in straw yield of paddy was noticed with respect to its distance from the teak row. However, numerically higher straw yield was noticed at 2 to 4 m distances from the teak row as compare to 0 to 2 m.

Fertilizer levels applied to teak had significant effect on the straw yield of associated paddy crop (Fig 12). Application of FYM + 10:5:10 NPK g per plant to teak recorded significantly higher straw yield of paddy (3775 kg/ha) than with other fertilizer levels. Increase in straw yield of paddy due to application of FYM + 10:5:10 NPK g per plant over control and FYM + 30:15:30 NPK g per plant was 2.3 and 4.1 per cent, respectively.

Interaction between distance from teak row and fertilizer levels with respect to straw yield of paddy was significant. The straw yield was maximum in  $D_2 \times F_3$  (3802 kg/ha) followed by  $D_2 \times F_4$  and  $D_1 \times F_3$  which were at par but significantly superior to other combinations except  $D_1 \times F_1$ ,  $D_1 \times F_2$ ,  $D_2 \times F_1$  and  $D_2 \times F_6$ .

Table 21. Relative crop yield of paddy (%) as influenced by distance from teak row and fertilizer levels imposed on associated teak.

| Treatments                               | D <sub>1</sub> -0 to 2 m | D <sub>2</sub> -2 to 4 m | Mean    |
|------------------------------------------|--------------------------|--------------------------|---------|
| F <sub>1</sub> - Control                 | 99.0 a-c                 | 98.8 a-c                 | 98.9 bc |
| F <sub>2</sub> - Only FYM (2.5 kg/plant) | 100.1 a-c                | 99.4 a-c                 | 99.8 b  |
| F <sub>3</sub> - FYM + 10:5:10*          | 100.8 a-c                | 102.2 a                  | 101.5 a |
| F <sub>4</sub> - FYM + 15:7.5:15*        | 97.8 bc                  | 101.6 ab                 | 99.7 b  |
| F <sub>5</sub> - FYM + 20:10:20*         | 98.3 bc                  | 98.9 a-c                 | 98.6 bc |
| F <sub>6</sub> - FYM + 25:12.5:25*       | 97.7 c                   | 99.9 a-c                 | 98.8 bc |
| F <sub>7</sub> - FYM +30:15:30*          | 97.2c                    | 98.4 a-c                 | 97.7 c  |
| Mean                                     | 98.7                     | 99.4                     |         |
|                                          | Sem±                     | LSD (P = 0.05)           |         |
| Distance from teak row (D)               | 0.343                    | NS                       |         |
| Fertilizer levels (F)                    | 0.44                     | 1.16                     |         |
| Interaction                              | 1.44                     | 3.52                     |         |

\*NPK g per plant

LSD applicable to Duncan's multiple range test

DAS = Days after sowing

NS = Non significant

#### 4.2.1.8 Relative crop yield of paddy (Table 21)

Relative crop yield did not differ significantly due to the effect of distance of paddy crop from teak row. However, the relative crop yield was numerically higher at 2 to 4 m distance than at 0 to 2 m.

Fertilizer levels applied to teak showed a significant difference in relative crop yield (Fig 12). Significantly higher relative crop yield was noticed with FYM + 10:5:10 NPK g per plant (101.5%) than with other levels of fertilizer. Lowest relative yield was recorded with FYM + 30:15:30 NPK g per plant (97.7 %) which was on par with  $F_6$ ,  $F_5$  and  $F_1$ .

Interaction between distance from teak row and fertilizer levels showed significant influence on relative crop yield. The combination of  $D_2 \times F_3$  recorded highest relative crop yield (102.23%) which was on par with other combinations except  $D_1 \times F_4$ ,  $D_1 \times F_5$ ,  $D_1 \times F_6$  and  $D_1 \times F_7$ . The lowest relative crop yield was seen with  $D_1 \times F_7$  (97.17 %), which was on par with rest of the combinations except  $D_2 \times F_3$  and  $D_2 \times F_4$ .

#### 4.2.1.9 Total nutrient uptake by paddy grown in association with teak (Table 22)

Distance from teak row significantly influenced the uptake of nitrogen and potassium by paddy. Where as, phosphorus uptake was not affected. Uptake of N and K was significantly higher at 2 to 4 m distance (63.94 and 44. 69 kg/ha) than at 0 to 2 m (63.13 and 43.82 kg/ha). The extent of reduction in the nitrogen and potassium uptake was 1.28 and 1.98 per cent respectively at 0 to 2 m distance over uptake at 2 to 4 m distance.

Fertilizer treatments to teak showed significant influence on the uptake of nutrient by associated paddy. Uptake of N was highest with  $F_3$  (65.34 kg/ha) which was on par with the  $F_1$  (64.32 kg/ha) but significantly superior to other

Table 22. Uptake of nutrients (N, P and K ) by paddy as influenced by distance from teak row and fertilizer levels imposed on associated teak.

| Treatments                                | Nitrogen uptake (kg/ha) | Phosphorus uptake (kg/ha) | Potassium uptake (kg/ha) |
|-------------------------------------------|-------------------------|---------------------------|--------------------------|
| Distance from teak row                    |                         |                           |                          |
| D <sub>1</sub> - 0 to 2 m                 | 63.13 a                 | 13.49 a                   | 43.82 a                  |
| D <sub>2</sub> - 2 to 4 m                 | 63.94 b                 | 13.79 a                   | 44.69 b                  |
| Sem +                                     | 0.2451                  | 0.131                     | 0.2154                   |
| LSD (P = 0.05)                            | 0.741                   | NS                        | 0.65                     |
| Fertilizer levels                         |                         |                           |                          |
| F <sub>1</sub> - Control                  | 64.32 ab                | 13.49 ab                  | 44.97 ab                 |
| F <sub>2</sub> - FYM alone (2.5 kg/plant) | 64.08 bc                | 13.89 ab                  | 45.32 a                  |
| F <sub>3</sub> - FYM + 10:5:10*           | 65.34 a                 | 14.28 a                   | 45.44 a                  |
| F <sub>4</sub> - FYM + 15:7.5:15*         | 63.26 b -d              | 13.77 ab                  | 44.09 b                  |
| F <sub>5</sub> - FYM + 20:10:20*          | 62.51 d                 | 13.20 b                   | 43.14 b                  |
| F <sub>6</sub> - FYM + 25:12.5:25*        | 62.95 cd                | 13.72 ab                  | 42.96 b                  |
| F <sub>7</sub> - FYM +30:15:30*           | 62.28 d                 | 13.16 b                   | 42.83 b                  |
| Sem +                                     | 0.384                   | 0.309                     | 0.383                    |
| LSD (P = 0.05)                            | 1.184                   | 0.953                     | 1.183                    |
| Interactions                              |                         |                           |                          |
| D <sub>1</sub> x F <sub>1</sub>           | 64.26 a-d               | 13.29 b                   | 44.51 b-d                |
| D <sub>1</sub> x F <sub>2</sub>           | 64.75 ab                | 13.87 ab                  | 45.43 a-c                |
| D <sub>1</sub> x F <sub>3</sub>           | 64.62 a-c               | 13.75 ab                  | 46.00 ab                 |
| D <sub>1</sub> x F <sub>4</sub>           | 62.26 d -f              | 13.89 ab                  | 43.03 de                 |
| D <sub>1</sub> x F <sub>5</sub>           | 61.68 f                 | 13.17 b                   | 42.45 e                  |
| D <sub>1</sub> x F <sub>6</sub>           | 62.23 d-f               | 13.70 ab                  | 42.68 de                 |
| D <sub>1</sub> x F <sub>7</sub>           | 62.09 e-f               | 12.80 b                   | 42.59 de                 |
| D <sub>2</sub> x F <sub>1</sub>           | 64.37 a-c               | 13.68 b                   | 45.43 a-c                |
| D <sub>2</sub> x F <sub>2</sub>           | 63.40 b-f               | 13.90 ab                  | 45.21 a-c                |
| D <sub>2</sub> x F <sub>3</sub>           | 66.06 a                 | 14.82 a                   | 46.88 a                  |
| D <sub>2</sub> x F <sub>4</sub>           | 64.27 a-e               | 13.63 b                   | 45.17 a-c                |
| D <sub>2</sub> x F <sub>5</sub>           | 63.33 b-f               | 13.22 b                   | 43.83 c-e                |
| D <sub>2</sub> x F <sub>6</sub>           | 63.68 b-f               | 13.73 ab                  | 43.24 de                 |
| D <sub>2</sub> x F <sub>7</sub>           | 62.47 c-f               | 13.52 b                   | 43.07 de                 |
| Sem +                                     | 0.649                   | 0.3469                    | 0.569                    |
| LSD (P = 0.05)                            | 1.97                    | 1.15                      | 1.73                     |

\* NPK g per plant

MAP = Months after planting

LSD applicable to Duncan's multiple range test

Means followed by same subscripts do not differ significantly

treatments. Among interactions, nitrogen uptake was highest with the combinations of  $D_2 \times F_3$  (66.06 kg/ha), followed by  $D_1 \times F_2$  (64.75 kg/ha) and  $D_1 \times F_3$  (64.62 kg/ha) which were at par but significantly superior to other combinations except  $D_1 \times F_1$ ,  $D_2 \times F_1$  and  $D_4 \times F_4$ .

Phosphorus uptake was significantly higher with FYM + 10:5:10 NPK g per plant than with FYM + 30:15:30 NPK g per plant and FYM + 20:10:20 NPK g per plant, but was on par with other treatments. Among interactions, combination of  $D_2 \times F_3$  (14.82 kg/ha) showed maximum uptake of phosphorus followed by  $D_2 \times F_2$  (13.9 kg/ha) and  $D_1 \times F_4$  (13.89 kg/ha) which were at par but significantly superior to other combinations except  $D_1 \times F_2$ ,  $D_1 \times F_3$ ,  $D_1 \times F_6$  and  $D_2 \times F_6$ .

Uptake of potassium by paddy was significantly higher with FYM + 10:5:10 NPK g per plant (45.44 kg/ha) which was statistically on par with application of FYM alone and control but significantly superior to other treatments. In the interaction, the combination of  $D_2 \times F_3$  showed significantly higher uptake of potassium (46.88 kg/ha) than other combinations except  $D_1 \times F_2$ ,  $D_1 \times F_3$ ,  $D_2 \times F_1$ ,  $D_2 \times F_2$  and  $D_2 \times F_4$ .

#### **4.2.1.10 Soil moisture content (%) (Table 23)**

Soil moisture content did not vary significantly due to distance from the teak row. However, numerically higher soil moisture content was recorded at 2 to 4 m distance (Fig 13).

Moisture content in soil varied significantly due to application of fertilizer to teak plants. The highest soil moisture content was recorded with FYM + 10:5:10 NPK g per plant (22.06 %) which was on par with rest of the treatments except FYM + 30:15:30 NPK g per plant.

Table 23. Soil moisture content (%) as influenced by distance from teak row and fertilizer levels imposed on associated teak.

| Treatments                               | D <sub>1</sub> -0 to 2 m | D <sub>2</sub> -2 to 4 m | Mean             |
|------------------------------------------|--------------------------|--------------------------|------------------|
| F <sub>1</sub> - Control                 | 11.43 bc (19.73)         | 12.67 ab (20.88)         | 12.05 ab (20.23) |
| F <sub>2</sub> - Only FYM (2.5 kg/plant) | 12.25 bc (20.53)         | 14.24 a (22.14)          | 13.25 ab (21.39) |
| F <sub>3</sub> - FYM + 10:5:10*          | 14.33 a (22.22)          | 13.90 ab (21.89)         | 14.10 a (22.06)  |
| F <sub>4</sub> - FYM + 15:7.5:15*        | 13.41 ab (21.39)         | 13.23 ab (21.80)         | 13.32 ab (21.39) |
| F <sub>5</sub> - FYM + 20:10:20*         | 12.05 bc (20.36)         | 13.47 ab (21.47)         | 12.76 ab (20.88) |
| F <sub>6</sub> - FYM + 25:12.5:25*       | 12.23 bc (20.53)         | 13.33 ab (21.39)         | 12.72 ab (20.86) |
| F <sub>7</sub> - FYM +30:15:30*          | 10.68 c (19.09)          | 11.04 c (19.37)          | 10.86 b (19.28)  |
| Mean                                     | 12.49 a                  | 12.98 a                  |                  |
|                                          | Sem±                     | LSD (P = 0.05)           |                  |
| Distance from teak row (D)               | 0.24                     | NS                       |                  |
| Fertilizer levels (F)                    | 0.84                     | 2.59                     |                  |
| Interaction                              | 0.65                     | 1.96                     |                  |

\*NPK g per plant

LSD applicable to Duncan's multiple range test

DAS = Days after sowing

NS = Non significant

Figures in the parenthesis indicates angular transformed values

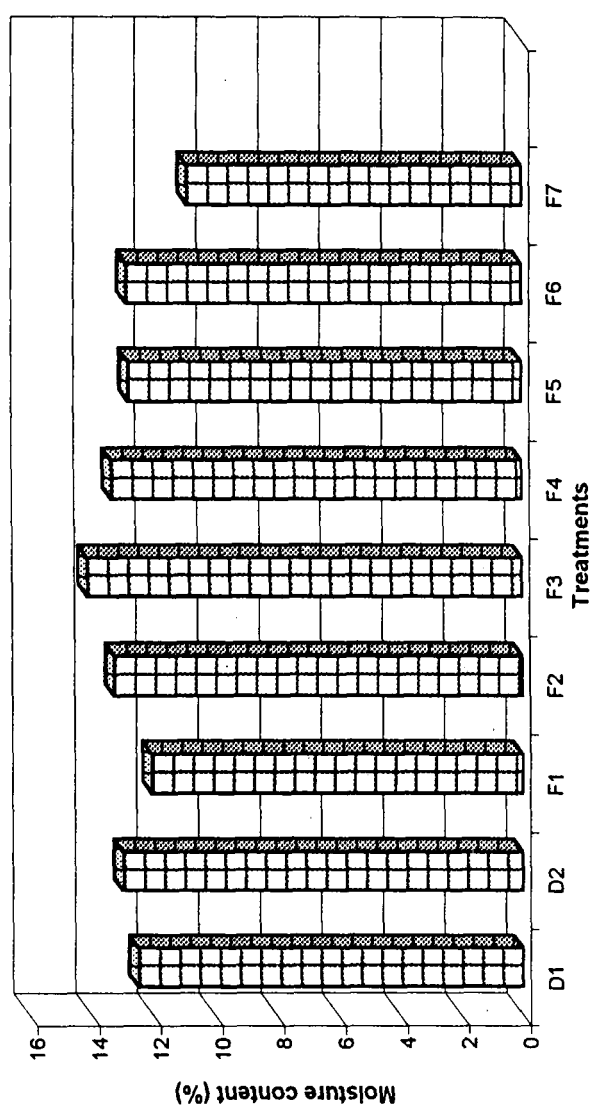


**Fig13. Moisture content (%) as influenced by growth of associated teak plants treated with various fertilizer levels and its distance from teak row**

Table 24. Average growth attributes of sole teak (with no paddy) and teak in association with paddy at various stages of growth

| Parameter                    | 14 MAP    |                 | 16 MAP    |                 | 18MAP     |                 |
|------------------------------|-----------|-----------------|-----------|-----------------|-----------|-----------------|
|                              | sole teak | teak with paddy | sole teak | teak with paddy | sole teak | teak with paddy |
| Height (cm)                  | 75.22     | 68.53           | 137.99    | 130.96          | 160.94    | 156.94          |
| No of leaves                 | 10.22     | 11.77           | 21.4      | 18.22           | 26.44     | 24.88           |
| No of main stem nodes/ plant | 6.44      | 5.74            | 12.77     | 14.22           | 13.66     | 15.66           |
| Collar diameter (cm)         | 2.96      | 2.89            | 3.88      | 3.49            | 3.942     | 3.86            |
| Crown diameter (cm)          | 74.3      | 72.4            | 82.62     | 78.12           | 86.8      | 83.78           |
| Leaf area (cm <sup>2</sup> ) | 3442.7    | 3532.10         | 6397.8    | 6491.4          | 6996.7    | 7128.33         |

MAP – Months after planting

Interaction between distance from teak row and fertilizer levels was significant. Combinations of  $D_1 \times F_3$  recorded highest soil (22.22 %) moisture content followed by  $D_2 \times F_2$  (22.14 %) which were at par but differed significantly with  $D_1 \times F_1$ ,  $D_1 \times F_2$ ,  $D_1 \times F_7$  and  $D_2 \times F_7$  combinations.

#### **4.2.2 Effect of paddy on growth parameters of teak (Table 24)**

At all the stages of teak growth height of teak was considerably higher with sole teak compare to teak with paddy. At 18 MAP, sole teak recorded 2.54 per cent increase in height over teak grown with paddy.

Number of leaves per plant was comparatively higher in teak with paddy at 14 MAP. Where as teak grown with paddy recorded reduced number of leaves in the subsequent stages (16 and 18 MAP).

At the early stage (14 MAP) number of main stem nodes per plant was higher with sole teak than in teak with paddy. However, in the subsequent stages (16 and 18 MAP), teak with paddy showed comparatively more number of nodes per plant (14.22 and 15.66, respectively).

Collar diameter was comparatively higher in sole teak than with paddy at all the three stages. Similar trend was noticed with respect to crown diameter. Leaf area was comparatively higher in teak grown with paddy than in sole teak at all the stages.

## DISCUSSION

## V DISCUSSION

Results of the field experiment conducted to find out optimum fertilizer levels to one year old bund planted teak and its effect on associated paddy crop are discussed in this chapter.

### 5.1 Effect of fertilizer levels on the growth of teak

Application of fertilizer significantly influenced the growth of teak at all stages of study. At all the stages there was significant increase in height with application of FYM + 30:15:30 NPK g per plant which was on par with FYM + 25:12.5:25 NPK g per plant and FYM + 20:10:20 NPK g per plant. The response to higher levels of fertilizers in terms of height growth was more pronounced in later stages (16,18 and 20 MAP) than in early stage (14 MAP). At 20 MAP, increase in plant height due to application of FYM + 30:15:30 NPK g per plant over control and application of FYM alone was 123.8 and 113.8 per cent respectively (Table 4). This increase in height growth of teak might be due to increased uptake of plant nutrients which is evident from Table 15. Uptake of adequate nutrient led to production of higher photosynthates, which in turn increased the height. Similar results of increased plant height with application of fertilizer (urea) at 200 or 300 g per plant to 12 months old teak plants were reported by Bheemaiah *et al.* (1997).

Application of FYM alone did not influence the height growth of teak significantly compared to control at all stages. However, height growth was comparatively higher with FYM alone over control. This *might be due to*

smaller quantity of nutrient present in FYM in addition of its beneficial effect on soil properties. Gupta and Sharma (2001) also reported favourable effect of FYM on plant height of *Prosopis cineraria*.

It is interesting to note that significant height growth response in the present study was upto F<sub>5</sub> level (FYM + 20:10:20 NPK g per plant); where as, the same bund planted teak at early stage (8 MAP) responded upto 2.5 kg FYM + 30:15:30 NPK g per plant (Marigoudar). This might be due to residual effect of fertilizer applied during previous season and also due to absorption of nutrient from deeper soil layer as the root growth increased with advance in age.

Significant difference in collar diameter of teak was noticed due to different fertilizer levels at all stages of growth (Table 5). At 20 MAP, significantly higher collar diameter was observed with the application of FYM + 30:15:30 NPK g per plant (4.8 cm) which was on par with FYM + 25:12.5:25 NPK g per plant (F<sub>6</sub>) and FYM + 20:10:20 NPK g per plant (F<sub>4</sub>). The increase in collar diameter due to application of FYM + 30:15:30 NPK g per plant was to the tune of 15.6, 15.6, 62.1 and 80.9 per cent over F<sub>6</sub>, F<sub>5</sub>, FYM alone and control, respectively.

This increase in the collar diameter may be attributed to higher uptake of nutrients by plants, which helped in higher dry matter production and its distribution into main stem (Table 12). Swaminathan (1995) also obtained similar findings of substantial increase in the collar diameter with the application of fertilizers to teak.

Number of main stem nodes per plant in the treatment receiving FYM + 30:15:30 NPK g per plant was significantly higher than rest of the treatments

at initial stage (14 MAP). Where as, at later stages (16, 18 and 20 MAP), response obtained was upto F<sub>5</sub> (FYM + 20:10:20 NPK g per plant) and there was no significant increase in main stem nodes with higher fertilizer level. At 20 MAP, FYM + 30:15:30 NPK g per plant increased the main stem nodes to an extent of 93.3 and 72.8 per cent over control and application of FYM alone, respectively. This increase in main stem nodes may be the due to application of higher fertilizer level which consequently increased plant height. The increase in the number of nodes per plant in turn was responsible for significant increase in the number of leaves per plant with higher level of fertilizer application, which is evident from Table 7. These results are in conformity with the findings of Gupta *et al.*, (1993) who reported that combination of N and P produced 4 times more number of leaves per plant than in control (with no fertilizer).

Fertilizer levels had a significant influence on the leaf area per plant at all the stages studied. At 18 MAP, FYM + 30:15:30 NPK g per plant showed significantly higher leaf area (9381.62 cm<sup>2</sup>) which was on par with FYM + 25:12.5:25 NPK g per plant and FYM + 20:10:20 NPK g per plant. Extent of increase in the leaf area with application of FYM + 30:15:30 NPK g per plant was 249.6 and 178.0 per cent over control and FYM alone, respectively. The increase in leaf area noticed with higher levels of fertilizer application may be due to more number of leaves per plant. This may be attributed to better uptake of applied nutrients in the form of N, P and K at higher levels (Table 15) which caused higher production of photosynthates and their allocation into leaves. These results are in conformity with the findings of Swaminathan

(1995) who noticed increased leaf area per plant in fertilized plots compared to control.

There was significant variation in crown diameter due to different fertilizer levels at all stages studied (Table 9). At 18 MAP, FYM + 30:15:30 NPK g per plant resulted in significantly higher crown diameter (92.78 cm) which was statistically on par with FYM + 25:12.5:25 NPK g per plant and FYM + 20:10:20 NPK g per plant. Application FYM + 30:15:30 NPK g per plant showed 106.1 and 74.9 per cent increase in crown diameter over control and FYM alone, respectively. The increase in crown diameter per plant was in turn responsible for significantly higher crown spread. It is evident from Table 10, FYM + 30:15:30 NPK g per plant showed significantly higher crown spread at all stages which was on par with FYM + 25:12.5:25 NPK g per plant and FYM + 20:10:20 NPK g per plant at 14 and 16 MAP. At 18 MAP, application of FYM + 30:15:30 NPK g per plant showed 20.2, 185.3 and 321.7 per cent increase over FYM + 25:12.5:25 NPK g per plant, FYM alone and control, respectively. This increase in crown diameter was due to higher fertilizer levels is mainly attributed to increased number of leaves and leaf area per plant. More number of leaves and higher leaf area caused higher photosynthetic efficiency resulting ultimately into larger canopy structure. These results are in line with the findings of Prasad *et al.* (1986) who noticed that higher levels of fertilizer increased canopy size of teak plant.

Internodal length was not influenced significantly with the application of varied levels of fertilizer (Table 11). This indicates that increased height growth due to higher levels of fertilizer was mainly due to increased number of stem nodes rather than increased internodal length.

The volume of the main stem differed significantly due to the application of different levels of fertilizer (Table 11). Application of FYM + 30:15:30 NPK g per plant recorded significantly higher stem volume (2195.31 cm<sup>3</sup>), which was on par with FYM + 25:12.5:25 NPK g per plant and FYM + 20:10:20 NPK g per plant fertilizer levels. Application of FYM + 30:15:30 NPK g per plant registered 549, 396, 72.73 and 55.69 per cent increase in main stem volume over control, FYM alone, FYM + 25:12.5:25 NPK g per plant and FYM + 20:10:20 NPK g per plant, respectively. The higher volume may be due to the higher height and collar diameter that resulted due to application of higher levels of fertilizer. Mutanal (1998) also reported that teak stem volume significantly increased by 16.3 per cent with the application of 200:50:200 NPK kg per ha over 100:50:100 NPK kg per ha.

Dry matter production per plant and its distribution varied significantly due to application of different levels of fertilizer. Application of FYM + 30:15:30 NPK g per plant produced the highest total weight per plant, which was on par with F<sub>5</sub> and F<sub>6</sub>. Per cent increase in total dry weight per plant due to application of FYM + 30:15:30 NPK g per plant was 218.2, 148.6 and 3.1 per cent over control, FYM alone and FYM + 25:12.5:25 NPK g per plant, respectively. This increased dry matter production with higher levels of fertilizer may be attributed to higher photosynthetic efficiency, which in turn was due to increased leaf area per plant (Table 8). Banerjee *et al.* (1999) also reported that combined application of N and P produced higher total biomass than control.

The distribution of dry matter in stem was almost twice the dry matter distribution in branches and leaves. This may be due to greater translocation

of photosynthates in to mainstem. Singh and Baneerjee (1994) also observed that stem contributed major share to the total biomass of *Albizzia procera* with increased level of fertilizer application.

Net increment in height over 8 months period was significantly higher with FYM + 30:15:30 NPK g per plant which was on par with F<sub>6</sub> and F<sub>5</sub>. The height increment with FYM + 30:15:30 NPK g per plant was 171.37 and 136 per cent higher over control and application of FYM alone, respectively. This can be attributed to significant increase in height growth due to higher fertilizer levels. Similarly, combined application of FYM and inorganic fertilizers resulted in higher net increment in stem nodes per plant. This may be due to significant effect of fertilizer levels on number of main stem nodes. However, net increment in the collar diameter was not influenced significantly by different fertilizer levels despite the significant effect on collar diameter. This indicates that extent of increase in collar diameter due to fertilizer levels was lower.

Form factor differed significantly due to fertilizer levels. Higher form factor was noticed in control and application of FYM alone which was on par with the treatments F<sub>3</sub> and F<sub>4</sub>. Lowest form factor was with FYM + 20:10:20 NPK g per plant and FYM + 25:12.5:25 NPK g per plant followed by FYM + 30:15:30 NPK g per plant, which were at par. This decrease in form factor with higher levels of fertilizer may be due to increased height growth and consequent tapering of the main stem.

## **5.2 Tree - crop interaction**

In agroforestry systems perennials and annuals are grown in close proximity with each other. The interactions are bound to take place between

these two components for the limited growth resources. These interactions may be both positive and negative. The balance between these two determines the over all effect on given agroforestry system. The knowledge of interactions for different components is helpful for the proper management of agroforestry systems for sustainable production.

### **5.2.1 Effect of distance from teak row on growth and yield of paddy**

Distance from teak row significantly influenced the plant height of paddy at 120 DAS and at harvest. At both stages, plant height of paddy was significantly lower at 0- 2 m distance than at 2 – 4 m distance. This reduction in the plant height of paddy at 0- 2 m distance may be due to competition posed by associated teak plants for growth resource mainly nutrients (N and K). This is evident from Table 22, where uptake of nitrogen and potassium by paddy was significantly lower at 0-2 m distance than at 2-4 m distance. Moreover, there was no significant variation in soil moisture content at both the distances (Table 23) indicating lesser competition for moisture.

Similar trend in the number of tillers per meter row length at different distances from teak row was observed at all stages of paddy except at initial stage (Table 18). However, reduced plant height and number of tillers due to distance from teak row had no significant impact on total dry weight per plant indicating lesser contribution of these parameters to total dry weight.

There was no significant difference in the panicle length of paddy (at 120 and at harvest) and 1000 grain weight due to its distance from teak row, which in turn resulted in non significant variation in grain and straw yield of paddy. Thus, although there was significant variation in plant height and number of tillers of paddy due to distance from teak row, such variation was

not observed in grain yield and straw yield of paddy. This is also evident from non significant difference in relative crop yield of paddy (Table 21) indicating that paddy yield at both distance were almost similar.

### **5.2.2 Effect of fertilizer levels imposed on teak on associated paddy**

Application of different levels of fertilizer to teak plants significantly affected the plant height of associated paddy crop at 120 DAS. At 120 DAS, higher plant height was noticed with FYM alone (87.98 cm) which was on par with rest of the treatments except control. This variation can be attributed to higher growth of teak with higher fertilizer levels consequently resulting in higher height growth due to competition for nutrients. However plant height of paddy was significant at harvest stage this may be due to physiological maturity of plant.

Fertilizer levels imposed on teak plants showed significant influence on dry weight per plant of associated paddy at all stages except 120 DAS. At harvest, dry weight per plant was maximum with FYM + 10:5:10 NPK g per plant (F<sub>3</sub>) followed by FYM + 15:7.5:15 NPK g per plant, control, FYM alone and FYM + 20:10:20 NPK g per plant which were at par but significantly superior to other treatments. This indicates that dry weight per plant of paddy reduced at higher levels of fertilizer (F<sub>6</sub> and F<sub>7</sub>). This was mainly because of greater competition offered by teak plants, as their growth was higher with higher fertilizer levels. However, the difference in dry weight was not significant at 120 DAS which may be attributed to greater translocation of photosynthesis to reproductive structures as it coincide with grain development stage.

Fertilizer levels imposed on teak plants significantly influenced the number of tillers per meter row of associated paddy at all the stages. At harvest, number of tillers was significantly more with FYM alone (90.67) than other levels of fertilizer except control ( $F_1$ ). This decrease in number of tillers at higher levels of fertilizer levels may be due to increased competition for growth resources. With FYM + inorganic fertilizer treatments, the growth of teak was higher, which might have led to increased competition with associated paddy resulting in reduced number of tillers.

There was no significant difference in the panicle length and 1000 grain weight due to fertilizer levels. Despite the non significant variations in these parameters, the grain yield per hectare showed a significant difference, indicating lesser contribution of these parameters to grain yield. The maximum grain yield (1364 kg/ha) was observed with the application of FYM alone which was on par with treatments control and FYM + 15:7.5:15 NPK g per plant. Application of FYM+ 30:15:30 NPK g per plant recorded 3.71 per cent decrease in grain yield compare to FYM alone application. This may be due to significant difference in the tillers per meter row length. At higher fertilizer levels to teak, number of tillers of associated paddy reduced significantly (Table 18) which ultimately led to reduction in the grain yield. The trend in straw yield of paddy due to fertilizer levels imposed on associated teak was almost similar.

Nissen *et al.* (1999) also reported yield reduction of cabbage planted near nine month old *Eucalyptus torrellicana* declined due to shading and below ground competition for moisture. Thomas and Mead (1992) reported that two year old *Pinus radiata* competed with arable crops underneath for

nutrients and it took 20 per cent of the labeled N fertilizer which were applied to adjoining arable crops.

Thus, yield reduction in paddy was more with higher growth of teak plants due to higher fertilizer levels. Higher reduction in soil moisture (Table 23) and nutrient uptake by paddy (Table 22) at higher levels of fertilizers where the teak growth is higher indicate the below ground competition of moisture and nutrients.

This competition for resource may be due to presence of teak roots at the top layers of soil, which might have overlapped with root zones of the paddy crop. Soil moisture also has a pronounced effect on the uptake of plant nutrients. Low level of extractable water in the root zone retards nutrient availability by impairing process involved in nutrient uptake. So, the reduced uptake of nutrients by paddy with higher levels of fertilizer imposed on associated teak can be attributed to reduced soil moisture content. Parvez Ahmed (1989) also reported that significantly lower yields of crops in adjoining eucalyptus tree lines was due to low soil moisture content.

### **5.2.3 Interaction effect of distance from teak row and fertilizer levels on associated paddy crop**

Interaction between distance from teak row and fertilizer levels imposed on teak showed a significant difference in the plant height of associated paddy at all stages of growth under study. At harvest, the plant height was highest with the combination of  $D_1 \times F_2$  (88.21 cm) which was on par with all other combinations except  $D_1 \times F_6$ ,  $D_1 \times F_7$  and  $D_2 \times F_6$ . Thus, the combination of closer distance and higher fertilizer level reduced the plant

height to a greater extent. This may be due to greater competition for moisture and nutrients at these combinations (Table 22 and 23).

Dry weight per plant showed almost the same trend due to interaction effect of distance from teak row and fertilizer levels applied to teak. At harvest, dry weight was lowest with  $D_1 \times F_7$  which was on par with  $D_1 \times F_6$ . This decrease in dry weight may be due to increased competition for nutrients and moisture as competitive effect was intense due to higher growth of teak and closer distance from teak plants in those combinations.

Interaction between fertilizer levels and distance from teak row had almost similar influence on number of tillers per meter row length of paddy at *all stages* (Table 18). Lesser number of tillers due to combination of closer distance and higher fertilizer level might have also contributed for lower dry weight per plant in those combinations.

Grain yield of paddy was significantly influenced by interaction between distance from teak row and fertilizer levels. The grain yield was significantly higher in  $D_2 \times F_2$  (1379 kg/ha). This increase in grain yield may be due to more number of tillers per meter row and higher panicle length (Table 19). The grain yield was significantly lower with combinations of closer distance from teak row and higher fertilizer levels ( $D_1 \times F_4$ ,  $D_1 \times F_5$ ,  $D_1 \times F_6$  and  $D_1 \times F_7$ ). The intense competition for moisture and nutrients in these combinations resulted in reduced number of tillers and panicle length which might have led to reduced grain yield per hectare.

Interaction between distance from teak row and fertilizer levels had almost similar effect on straw yield of paddy (Table 20). The decrease in straw yield in the combinations involving closer distance and higher fertilizer

levels may be ascribed to lower dry weight per plant and lesser tillers in these combinations which in turn were due to increased competition for nutrients and moisture.

Chandrashekaraiah (1986) also attributed reduction in yields of maize and sorghum adjoining tree lines to the competition for moisture and nutrients.

### **5.3 Effect of paddy on associated teak**

Plant height and collar diameter of the teak grown with paddy was comparatively lower at all the stages of the teak growth. At 18 MAP the reduction in plant height and collar diameter was to the extent of 3.6 and 3.86 per cent, respectively, in teak grown with paddy over teak with paddy over teak with out paddy. This reduction may be due to the competition offered by adjacent paddy crop.

Number of leaves per plant was comparatively higher in teak grown with paddy at initial stage (14 MAP); whereas, in subsequent stages number of leaves were reduced. Despite the reduced number of leaves, leaf area per plant was comparatively higher in teak grown with paddy. This may be due to larger size of leaves. Numerically higher values of parameters like number of mainstem nodes per plant and leaf area per plant in teak grown with paddy compared to sole teak might be due to beneficial effect of cultural operations done to paddy. Although, there were numerical variations in growth parameters of teak grown with and without paddy, over all growth of teak was not affected substantially by associated paddy crop. Further detailed studies with appropriate statistical designs may be required to explain such variations.

## **SUMMARY**

## VI SUMMARY

Introduction of perennial component in the existing farming system is one of the options available to improve productivity. Teak is often preferred to grow on farmlands due to its varied advantages. There is ample scope to introduce teak on terrace bunds of upland paddy areas. Information on optimum quantity of nutrients to be applied for achieving vigorous growth in initial stages and the effect of bund planted teak on adjoining arable crops is presently lacking. To tackle this problem, a field experiment was carried out to find out optimum level of fertilizer and tree crop interaction during 2001-2002 at ARS, Mundagod. The findings of the experiment are summarized in this chapter.

- The growth parameters of teak viz. plant height, collar diameter, number of main stem nodes, number of leaves, leaf area, crown diameter, volume of main stem and dry matter production were significantly influenced due to fertilizer at all stages of growth.
- Application of FYM + 30: 15: 30 NPK g per plant recorded significantly higher plant height which was statistically on par with FYM + 25: 12.5: 25 NPK g per plant and FYM + 20: 10: 20 NPK g per plant at 20 MAP. Increase in plant height due to application of FYM + 30: 15: 30 NPK g per plant over control and application of FYM alone was 123.8 and 113.8 per cent, respectively, at 20 MAP.
- At 20 MAP, Collar diameter was significantly higher with FYM + 30: 15: 30 NPK g per plant (4.83) which was on par with FYM + 25: 12.5: 25 NPK g per plant and FYM + 20: 10: 20 NPK g per plant. The increase in collar

diameter due to application of FYM + 30: 15: 30 NPK g per plant was 80.9 and 62.1 per cent over control and application of FYM alone, respectively, at 20 MAP.

- Significantly higher number of main stem nodes per plant was observed in case of FYM + 30: 15: 30 NPK g per plant (19.04) which was on par with FYM + 25: 12.5: 25 NPK g per plant (17.66) and FYM + 20: 10: 20 NPK g per plant (16.28). Increase in number of main stem nodes with FYM + 30: 15: 30 NPK g per plant was 93.3 and 72.8 per cent over control and FYM alone application, respectively, at 20 MAP.
- At 18 MAP, application of FYM + 30: 15: 30 NPK g per plant showed significantly higher leaf area (9381.52) which was on par with FYM + 25: 12.5: 25 NPK g per plant and FYM + 20: 10: 20 NPK g per plant. Extent of increase in the leaf area with the application of FYM + 30: 15: 30 NPK g per plant was 249.6 and 178.0 per cent over control and FYM alone, respectively.
- Increase in crown diameter with the application of FYM + 30: 15: 30 NPK g per plant was 106.1 and 74.9 per cent over control and application of FYM alone, respectively, at 18 MAP.
- Application of FYM + 30: 15: 30 NPK g per plant showed significantly higher crown spread ( $0.679 \text{ m}^2$ ) compare to all other treatments at 18 MAP. The crown spread was lowest in control, which was on par with the treatments FYM alone and FYM + 10: 5: 10 NPK g per plant. Application of FYM + 30: 15: 30 NPK g per plant showed 20.2, 185.3 and 321.7 per

cent increase in crown spread over FYM + 25: 12.5: 25 NPK g per plant, FYM alone and control, respectively.

- Volume of main stem was significantly higher with the application of FYM + 30: 15: 30 N, P and K g per plant (2195.63 cm<sup>3</sup>) which was on par with FYM + 25: 12.5: 25 NPK g per plant and FYM + 20: 10: 20 NPK g per plant. Application of FYM + 30: 10: 30 NPK g per plant registered 549 and 396 per cent increase over control and FYM alone, respectively.
- Total dry matter production per plant was highest with FYM + 30: 15: 30 NPK g per plant (1030.93 g) which was on par with FYM + 20: 10: 20 NPK g per plant and FYM + 25: 12.5: 25 NPK g per plant. The percent increase in total dry matter production per plant due to FYM + 30: 15: 30 NPK g per plant was 218.2, 148.6 and 3.1 per cent over control, FYM alone and FYM + 25: 12.5: 25 NPK g per plant, respectively. Similar trend was observed in dry matter distribution in different parts (main stem and branches and leaves) due to application of different levels of fertilizers. Dry matter accumulation in main stem was almost twice the dry matter accumulation in branches and leaves.
- Fertilizer use efficiency was highest with the application of FYM + 30: 15: 30 NPK g per plant followed by FYM + 25: 12.5: 25 NPK g per plant and FYM + 20: 10: 20 NPK g per plant, which were at par but differed significantly with rest of the treatments.
- Plant height of paddy was significantly higher at 2 to 4 m distances compare to 0 to 2 m distance at harvest stage. Application of fertilizer levels and their interaction with distance from teak row influenced the

plant height of paddy significantly at harvest stage. The higher plant height was noticed with FYM alone (87.51 cm) which was on par with rest of the treatments except FYM + 20: 10: 20 NPK g per plant. Among interactions, the combinations of  $D_1 \times F_2$  (88.21 cm) recorded significantly higher plant height which was on par with all other combinations except  $D_1 \times F_6$ ,  $D_1 \times F_7$  and  $D_2 \times F_6$ .

- Distance from teak row did not influence the dry weight per plant of paddy significantly at all stages of growth. Application of FYM + 10: 5: 10 NPK g per plant recorded maximum dry weight per plant (20.85 cm) at harvest stage. Among Interactions, combinations of  $D_2 \times F_3$  (21.01 g) showed maximum dry weight per plant compare to all other combinations except  $D_2 \times F_4$ ,  $D_1 \times F_4$  and  $D_1 \times F_3$ .
- Numbers of tillers were significantly higher at 2 to 4 meter distance compare to 0 to 2 m distance at all the stages. At harvest, application of FYM alone showed significantly more number of tillers (90.67) than other levels of fertilizer except control. Among interactions between distance from teak row and fertilizer levels, maximum number of tillers were noticed in the combination of  $D_2 \times F_2$  followed by  $D_1 \times F_2$ ,  $D_2 \times F_1$  and  $D_2$  and  $F_6$ .
- No significant difference was observed in 1000 grain weight of paddy due to distance from teak row, fertilizer levels and their interactions.
- Grain yield of paddy did not differ significantly with respect to its distance from teak row. Application of FYM alone to teak recorded maximum grain yield in associated paddy. Application of FYM + 30: 15: 30 NPK g per plant to teak recorded 3.71 per cent decrease in grain yield of associated

paddy compare to application of FYM alone. Among interactions, the grain yield was significantly higher in  $D_2 \times F_2$  (1379 kg/ha) which was on par with rest of the treatments except  $D_1 \times F_4$ ,  $D_1 \times F_5$ ,  $D_1 \times F_7$  and  $D_2 \times F_7$ .

- Straw yield of paddy was not influenced due to its distance from teak row. Application of FYM + 10: 5: 10 NPK g per plant recorded 2.3 and 4.1 per cent increase in straw yield of paddy over control and FYM + 30: 15: 30 NPK g per plant. The combinations of  $D_2 \times F_3$  (3802 kg/ha) recorded maximum straw yield which were at par with  $D_2 \times F_4$  and  $D_1 \times F_3$ .
- Relative crop yield was significantly higher with FYM + 10: 5: 10 NPK g per plant than with other levels of fertilizer. In the interaction, combination of  $D_2 \times F_3$  (102.23) recorded highest relative crop yield which was on par with other combinations except  $D_1 \times F_5$ ,  $D_1 \times F_6$  and  $D_1 \times F_7$ .
- Uptake of N and K was significantly higher at 2 to 4 m distance than at 0 to 2 m distance. The extent of reduction in N and K uptake was 1.28 and 1.98 per cent, respectively at 0 to 2 m distance. Uptake of N, P and K was highest with FYM + 10: 5: 10 NPK g per plant compare to all other treatments. In interaction studies the combination  $D_2 \times F_3$  recorded highest uptake of N, P and K.
- Soil moisture content did not vary significantly due to distance from teak row. Moisture content in soil showed significant difference to the application of fertilizer levels and soil moisture content was maximum with FYM + 10: 5: 10 NPK g per plant (22.06 %) which was on par with all other treatments except FYM + 30: 12.5: 30 NPK g per plant. In interactions, combination of  $D_1 \times F_3$  (22.22 %) recorded highest soil moisture content

followed by  $D_2 \times F_2$  which were on par but differed significantly with  $D_1 \times F_1$ ,  $D_1 \times F_2$ ,  $D_1 \times F_7$  and  $D_2 \times F_7$  combinations.

- Sole teak recorded higher height, number of leaves, collar diameter crown diameter compare to teak with paddy at 18 months after planting. Whereas, number of main stem nodes and leaf area per plant was higher in teak grown with paddy.

**Future line of work**

1. In the present study, application of 2.5 kg FYM + 20:10:20 NPK g per plant to teak was found optimum. So, there is a need to find out optimum quantity of nutrients in subsequent years as the requirement varies with advance in age as well as residual effect of nutrients applied during previous year.
2. Quantity of FYM to be applied year after year need to be worked out as a common dose of 2.5 kg per tree is applied in the present study.
3. Further studies on tree-crop interaction are required as the effect of perennial component increases with increase in age.
4. Suitable methods to check natural vegetation on terrace bunds and its effect on fertilizer use efficiency may be worked out. Alternatively, possibility of introducing suitable legume forages on terrace bunds may be explored so as to reduce the fertilizer requirement of bund planted teak.

## REFERENCES

Released on — — — —  
28 AUG 2008

U. A. S.  
University Library  
DHARWAD.

Acc. No. Th 7018

## VII REFERENCES

- \*ABOU DEYA, I. B., 1999, Productivity of *Acacia saligma* under siwa mobile dunes as influenced by N, P and K fertilizer. *Desert Institute Bulletin*, Egypt, **46** (2): 365 – 372.
- AHMED, P., 1989, Eucalyptus in agroforestry: its effect on agriculture production and economics. *Agroforestry Systems*, **8**: 31-38.
- ANANTHAPADHMANABHA, H. S., NAGAVENI, H. C. VIJAYALAKSHMI, G. AND SOMASHEKAR, P. V., 1998, Comparative effect of inorganic and biofertilizer on growth of teak plants. *Indian Journal of Forestry*, **21**(1): 1-3.
- ARAVIND, S., 1987, Evaluation of dynamics of soil K and physical properties under continuous fertilization and cropping. *M.Sc.(Ag) Thesis*, Tamil Nadu Agricultural University, Coimbatore.
- ARDEN-CLARKE, C. AND HODGES, R. D., 1988, The environmental effect of conventional and organic or biological farming. II Soil Ecology, soil fertility and nutrient cycling. *Biology Agriculture and Horticulture*, **5**: 233-287.
- \*ARIFIN, M., 1983, Enlargement of teak planting space in inter cropping system. *Duta Rimba*, **9**: 57 – 59.
- ASHISH MISHRA AND YOGESH MISHRA, 1999, Influence of different nitrogen source on the growth of *Albizia procera* on fly ash. *Environment and Ecology*, **17** (9): 866 – 890.
- BALASUBRAMANIYAN, V., 1983, Alley cropping: Could it be alternative to chemical fertilizers in Ghana? A paper presented at the 3<sup>rd</sup> National Maize

Workshop held at Kwadeso Agriculture College, Kumasal, Ghana, February 1-3.

BALASUBRAMANIYAN, P. AND PALANIAPPAN, 2001, *Principles and practices of Agronomy*, Agrobios Publication . Jodhpur, pp. 586.

BANERJEE, S. K., SINGH, A. K., SANKAR, S. D. AND KASHYAP, M. K., 1999, Evaluation of effectiveness of compost and nitrogenous fertilizer accumulation of *Dalbergia sissoo* in iron mine over burden area. *Advances in Forestry Research in India*, **22**: 145- 161.

BAPAT, A. R. AND PAULARI, M. M., 1998, Teak fruit treatment machine – a prototype. *Indian Forester*, **121** (6): 545-549.

BASAVARAJU, K., 1997, Performance of aromatic crops in eucalyptus based agroforestry system. *Journal of Environmental Sciences*, **9** (4): 130-136.

BEBARTA, K. C., 1999, *Teak ecology, silviculture, management and profitability*. International Book Distributors, Dehra Dun , India, pp. 67.

BHASKAR, V., ARALI, A. AND SHANKARLINGAPPA, B. C., 1991, Alleviation of alleopathy effects of eucalyptus hybrid through litter burning. *In Proceedings First National Symposium on Alleopathy in agroecosystem*, Hissar, India.

BHAT, R., 1988, Influence of some tree species on sunflower and pigeonpea cropping system. *M. Sc. Thesis*, University of Agriculture Sciences, Dharwad.

- BHEEMAIAH, G., SUBRAMANIYAN, M. V. R. AND SYED ISMAIL, 1997, Performance of teak under different irrigation and fertilizer management practices. *Indian Forester*, **123** (2): 1171-1175.
- BLACK, J. D. F., 1965, Trickle irrigation, A review. *Horticulture Abstracts*, **46**: 69-74.
- CANNEL, M. G. R., 1983, Plant management in agroforestry: Manipulation of trees. In *Plant Research and Agroforestry, International Council for Research on Agroforestry*, Nairobi, Kenya, pp. 455-486.
- CAZRI, 1992, Annual report, Central Arid Zone Research Institute, Jodhpur, pp. 34-35.
- CHANDRASHEKARIAH, A. M., 1986, Investigation on agroforestry systems in black soil of transitional tract of Karnataka. *Ph.D. Thesis*, University of Agricultural Sciences, Bangalore.
- \*CHANTRAPPA, S., 1991, Agroforestry of Klang Dong Forest Station, *International Workshop on conventional and sustainable development*. 22-26 April, Bangkok, Thailand.
- CHATTERJEE, B. N., SINGH, K. L., PAL, A. AND MAITI, S., 1979, organic manure as a substitute for chemical fertilizer for high yielding varieties. *Indian Journal of the Indian Society of Soil Sciences*, **49** (3); 188 –192.
- DAGAR, J. C., GURUBACHAN SINGH, SINGH, N. T. AND SINGH, G., 1995, Evaluation of crops in agroforestry with teak, maharakh and tamarind on reclaimed salt affected soils. *Journal of Tropical Forestry Sciences*, **7**(4): 623-634.

- DEOL, G. S. AND KHOSLA, P. K., 1983, Provenance related growth response of *Populus ciliata* wall. Royle to nitrogen fertilization. *Indian Forester*, **109** (1): 33-40.
- DHILLON, K., COCK, R. AND BOWEN, C. K., 1982, Effect of row management on light interception and in eucalyptus based agroforestry. *Journal of Agricultural Sciences, Cambridge*, 104: 263-270.
- \*DONALD, LEROY, HARVEY, J., STANGEL. AND JOHN PESEK, 1963, *Fertilizer technology and usage*, Soil Science Society of America, Madisoo, W.S.
- DUTTA, A. K. AND PANTHANIAN, V., 1986, *Leucaena Research reports*, **7**: 39-41.
- GAJANENI, J. AND JORDAN, D. F., 1989, Diversified agroforestry system. *Symposium of Agroforestry system and technologies*. Bogor, Indonesia.
- GIRCHURU, M. P. AND KANG, B. J., 1989, *Colliandra calothyrsus* (meissen) in an alley cropping system with sequentially cropped maize and cowpea in south western Nigeria. *Agroforestry Systems*, **9**: 191-203.
- \*GLASER, B. AND DRESCHER, P., 1992, Relation between available soil phosphorus and the foliar phosphate content of teak in West Africa. *Zeitschrift furpt lan Zenernahrung and Bondenkunde*, **155** (2): 115-119.
- GOMEZ, K. A. AND GOMEZ. A. A., 1984, *Statistical procedures for Agriculture Research*. An International Rice Research Institute Book, wiley – International Sciences publication, New York, USA, pp. 680.

- GREWAL, S. A., MUGHAL, A. H. AND MAKAYA, A. S., 1995, Fertilizer response by eucalyptus on initial growth parameter. *Indian Forester*, **123** (4): 47- 50.
- GUPTA, B. N., SINGH, A. K., BHOWMIK, A. K., SINGH, R. B. AND BANERJEE, S. K., 1993, Response of fertilizer on growth and biomass production of *Pithecellobium dulce* in coal mine overburden areas of Orissa. *Annals of Forestry*, **1** (2): 130-135.
- GUPTA, G. N., 1991, Effect of mulching and fertilizer on initial development of some different species. *Forest Ecology and Management*, **44** (2-4): 211-221.
- GUPTA, G. N., KUPPUSWAMY, V., CHOWDHARY, K. R., BOHRA, N. S., AND KUSUMLATA, 1994, Effect of fertilizers on early growth of *Ailanthus excelsa*. *Annals of Forestry*, **2** (1): 29-33.
- GUPTA AND SHARMA, A. S., 2001. Effect of multipurpose tree species on the yield of wheat. *Indian Journal of Forestry*, **24** (4): 484-489.
- HARSH, L. N. AND TEWARI, J. C., 1988, Tree crop interaction in agroforestry system, *In workshop Proceedings on agroforestry for rural needs*, Vol-IV pp. 535-541.
- HASE, H., FOELFER, H. AND CASTILLO, J. B., 1980, Nutrient requirement and production potential of teak plantation on alluvial sandy loam, Venezuela. "Proceedings International Union for Forest Research Organization working group SI 0709 Symposium on Wood production in the Geotropical, at Institute of Tropical Forester. Rioierdas, Puerto Rico.

- HESSE, P. R., 1984, In " Organic matter and rice. International Rice Research Institute, Los Banos, Laguna, Philippines. pp. 35- 42.
- HOODA, M. S., ANIL KUMAR. AND NANDAL, D. P. S., 1999, Productivity of chickpea with agroforestry species. *In Recent Advances in management of arid ecosystem, Proceeding Of a symposium held in India.*
- HUNTER, I. R. AND GRAHM, J. D., 1987, *New Zealand Journal of Science*, **12** (1): 49-61.
- ICRAF, 1993, Annual report, *International Council of Research on Agroforestry*, Nairobi, Kenya, pp.72-76.
- ITNAL, C. J., 1987, Investigation on agroforestry in northern dry zone of Karnataka. *Ph. D. Thesis*. University of Agricultural Sciences, Dharwad.
- JACKSON, M. L., 1967, *Soil chemical analysis*. Prentice Hall of India . Pvt. Ltd., New Dehli, pp. 498.
- JONSSON, K., STANL, N AND HAGBERG, P., 1988, Tree crop interactions in a parkland system in Burkina Faso. *Biology and Fertility of soil*. **23**: 50 –56.
- KAPPA, G., 1988. Forest village of the Thai State. *Plant Research and Development*, **27**: 8-11.
- KHADSE, V. M. AND BHARAD, G. M., 1996, Performance of annual crops under canopy of *Hardwickia binnata* Roxb. (Anjan) in agroforestry system. *Journal of soils and crops*, **6** (2): 151- 153.
- \*KHATTAK, C. M., SHEIK, M. I. AND KHALIQ, A., 1980, Growing trees with agricultural crops. *Pakistan Journal of Forestry*, **31**: 95 – 97.

- KING, K. F. S., WILSON, G. F. AND SIPKENS, K., 1981, Concepts of agroforestry. *In proceeding of an International Conference on International Cooperation of Agroforestry, International council for research in Agroforestry*, Nairobi, Kenya.
- KORWAR, G. R., 1992, Studies on alley cropping and agro silviculture system in black soils under dry land agriculture conditions. *Ph. D. Thesis*, University of Agricultural Sciences, Dharwad.
- KOUL, V. K., BHARADWAJ, S. D. AND KAUSHAL, A. N. M., 1995, Effect of N and P application on nutrient uptake and biomass production in *Bauhinia variegata* seedlings. *Indian Forester*, **121**(1): 14-22.
- KUMAR, K., MEELU, P. P., SINGH, Y. AND SINGH, B., 1992, Effect of continuous application of organic manures on the physical properties of soil in a rice wheat cropping system. *International Rice Research Newsletter*, **17**: 16-17.
- KUSHALAPPA, K. A., 1987, Short notes on trenching in teak planting, *My Forest*, **28** (1): 25-27.
- LAHIRI, A. K., 1989, Taungya based agroforestry trails in West Bengal. *Indian Forester*, **115** (3): 432-436.
- LAL, R., 1989, Agroforestry systems and soil surface management of a tropical Alfisol: I: Soil moisture and crop yields. *Agroforestry systems*, **8**: 7-29.
- LANG, J. P., JHU, J. AND LIU, T. Z., 1995, Related changes of wheat yield and photosynthetically radiation in Paulownia, wheat intercropping. *Field crop Abstracts*, **48** (4): pp 21.

- MAHETA, K. B., KUKADIA, M. U., VASHI, B. G. AND JADEJA, D. B., 1996, Effect of forest tree species on the yield potentials of intercrops. *Indian Forester*, **112**:651-653.
- MALIK, R. S. AND SHARMA, S. K., 1990, Moisture extraction and crop yield as a function of distance from row of *Eucalyptus tereticornis*. *Agroforestry System*, **12**: 187 – 195.
- MARATHAN, K. K., SANKARAN, K., KANASHUSANI, N. AND KRISHNAMOORTHY, K. K., 1978, Effect on continuous rotational cropping on the organic carbon and total nitrogen content in a black soil. *Journal of Indian Society of Soil Science*, **26**: 283-285.
- MARIGOUDRA, R. M., (2001), Effect of planting methods fertilizers on initial growth of teak grown on the bunds upland paddy area. *M. Sc. Thesis*, University of Agricultural Sciences, Dharwad.
- \*MEENA NAIR AND PETER, K. V., 1990, Organic, inorganic fertilizer and their combination on crop yield and storage life of hot chilli. *Vegetable Sciences*, **17** (1): 7-10.
- MEHATA, K. K. AND MONDAL, R. C., 1986, Operational research on reclamation of alkaline soil. Tree planting Indian Council for Agricultural Research Bulletin NO 12, Central Soil Fertility Research Institute, Karnal, pp. 44-52.
- MISHRA, L. C., 1979, Nitrogen cycling in greenlands at Kanpur. *Plant and Soil*, **53**: 361-371.

- MOHAMMED AFZAL, M. AND HAFEEZ., 1999, Effect of forest and fruit trees on wheat crop. *Pakistan Journal of Forestry*, 47 (1): 47 – 52.
- MUTANAL, S. M., 1998, Studies of teak based agroforestry system and fertigation. *Ph. D. Thesis*, University of Agricultural Sciences, Dharwad.
- MUTANAL, S. M., PRABAKAR, A. S. AND MADIWALR, S. L., 1999, Increment pattern in teal as influenced by fertigation. *My Forest*, **35** (1): 59-65.
- NADAGOUD, V. B., 1990, Performance of trees species and their influence on seasonal crops in agroforestry system under irrigation. *Ph. D. Thesis*, University of Agricultural Sciences, Dharwad.
- NAIR, P. K. R., 1983, Vanalakshmi, an agroforestry project I Kerala. *Indian Forester*, **106** (12): 829-836.
- NANDA KISHORE, 1987, Priliminary studies on the effect of phosphate fertilizers on teak plantation. *Indian Forester*, **133** (6): 391 – 394.
- \*NAZIR, M. S., AHMED, R. AND CHENNA, S. A., 1995, Quantitative analysis effect of shisham tree shade in wheat. *Pakistan Journal of Agriculture Research*, **14** (1): 12-17.
- NISSEN, T. M., MIDMORE, D. J. AND CABRARA, M. L., 1999, Above ground and below ground competition between inter cropped cabbage and young *Eucalyptus torelliana*. *Agroforestry System*, **46** (1): 83-93.
- PARVEZ AHMED, 1989, Eucalyptus in agroforestry, its effect on agriculture production and economics. *Agroforestry Systems*, **8**: 31-38.
- PIPER, C. S., 1966, Soil and Plant Analysis. Hans Publications, Bombay, pp. 236.

- PRAJAPATHI, M. C., VARMA, B., MITTAL, S. P., NAMBIAR, K. T. AND TIPPANNAVAR, B. S., 1971, Effect of lateral development of *Prosopis juliflora* roots on agriculture crops. *My Forest*, **20**: 186-193.
- PRASAD, K. G., KUMAR, D., CHANDRASEKARAN, J. J., MOHAN, S., MADAV NAIR, J. AND DEO, A. D., 1984, Fertilization of *Eucalyptus grandis* on severely truncated soil. *Indian Forester*. **110** (2): 132-141.
- PRASAD, R., SAH, A. K. AND BANDARI, A. S., 1986, Fertilization trials in ten and twenty year old teak plantations in Madhya Pradesh. *Journal of Tropical Forestry*, **2**(1): 15-20.
- PARTHIBAN, K. T. AND VINAY RAI, R. S., 1994, Trees on farmlands, their effects on soil fertility. *Annals of Forestry*, **8**: 31-38.
- PURI, S., KUMAR, A. AND SINGH, S., 1994, Productivity of *Cicer aurietinum* (Chickpea) under a *Prosopis cineraria* agroforestry system in the regions of India. *Journal of Arid Environments*, **27** (1): 85 – 98.
- RAM PRASAD, SAH, A. K. AND BHANDARI, A. S., 1986, Fertilizer trial in ten and twenty years old teak plantation in Madhya Pradesh. *Journal of Tropical Forestry*, **2**: 1, 47 – 52.
- RANGASWAMY, C. R., JAIN, S. H. AND SHARMA, C. R., 1991, Effect of inorganic fertilizer on seedlings of casuarina, sandal and tea. *My Forest*, **26** (4): 322-326.
- RAO AND RAMA MOHAN, M. S., 1990, Approaches to the management of denuded watershed in the peninsular India. *Indian Council for Agricultural Research*, New Delhi, 232-244pp.

- ROBERT, W., KEABOUALAPPA, B. AND MANIVANH, H., 1998, Teak, fruits trees and other perennials used by hill farmers on Northern Laos. *Agroforestry Systems*, **29** (1): 47-60.
- \*ROE, N. E., STOFFELLA, P. J. AND MACLEOD, D. A., 1993, Compost from various municipal solid waste seed stocks affects vegetable crops-II Growth yields and fruit and quality. *Journal of the American Society for Horticulture sciences*, **122**: 433-437.
- SAHU, M. P. AND MANHOT, M. C., 1988, Nutrient management in forestry plantations. *Advances in Forestry research in India*, **3**: 1 – 48.
- SANKARA REDDI, G. H. AND YELLAMMA REDDI, T., 1995, *Plant water relationships, in efficient use of irrigation water*. Kalyani Publishers, Ludhiana, pp. 79-81.
- SHAIKH, M. H. A., 2000, Forestry in the new millenium, *Indian Forester*, **126** (1): 103 – 110.
- SHANKARANARAYANA, K. A., HARSH, L. N. AND KATHYAL, S., 1987, Agroforestry in arid zones of India. *Agroforestry Systems*, **5**: 69-88.
- SHARMA, K. K., 1996, Agroforestry in farming system development. *Indian Forester*, **122** (7): 547-551.
- SHARMA, K. K., PRADEEP KHANNA AND GULATI, 1994, Influence of *Euaclyptus* shelter belts on fodder crop. *Indian Forester*, **122**: 655-664.

- SHARMA AND SINGH., 1992 , Perspective on the utilization of fruit and fodder trees in the mountains, This Ecological Carnage in the Himalaya, Dehradun, India, IBP.
- \*SHEPARD, R. K. AND LEMIN, R. C., 1989, Two year growth of eastern white pine as influenced by nitrogen application. *CFRO progress report*, College of Forest resource, University of Maine.
- SINGH, A. K. AND BANERJEE, S. K., 1994, Fertilizer response to *Albizia procera* in skeleton soil. *Advances in Research in Forestry in India*, **20**: 163-181.
- SINGH, K. AND SRIVASTAVA, B. K., 1988, Effect of various levels of nitrogen and phosphorus on growth and yield of chilli. *Indian Journal of Horticulture*, **45**: 319-324.
- SINGH, R. P., VAN DEN BELDT, R. J., HOCKING, D. AND KORWAR, G. R., 1986, Alley cropping in the semi arid regions of India. *Proceeding of workshop on alley cropping*, March 10-14, International Institute of Tropical Agriculture, Ibadan, Nigeria.
- SOUKAR, S. P. AND KUMBHARE, N., 1991, Phosphorus and potassium fertilizer on growth of teak seedlings. *Paper presented in Regional meeting of Silvicultural and Research Workers*. Conference held at Bhubaneswar, Orissa.
- \*SRIRAMACHANDRASHEKARAN, M. V., RAMANATHAN, G. AND RAVICHANDRAN, M., 1996, Effect of organic manures on the availability of nutrients in rice rhizosphere soil. *Oryza*, **33**: 126-131.

- SRIVASTAVA, R. L., GINWAL AND MOHIT GERA, H. S., 1983, Performance of seventeen different multipurpose tree species under semi arid region, Central India. *Indian Forester*, **112** (3): 542-548.
- STICKLER, WEADSON, S. AND POULI, 1961, Leaf are determination in grain sorghum. *Agrono. J.*, **53**: 187-188.
- SUBRAMANYAN, M. V. R., BHEEMAIAH, G. AND SYED ISMAIL, 1996, Compatibility of arable crops inter cropped with *Dalbergia sissoo* for sustainable rainfed agriculture. *Indian Forester*, **122** (7): 646-650.
- \*SUNDERLIN, W., 1992, Benefits, costs and equity analysis of a social forestry site in Central Java, Financial and economic analysis of agroforestry systems. *Proceedings of workshop*, Hawaii, USA, 261 – 270.
- SWAMINATHAN, C., 1995, Silvicultural studies on irrigated teak. *Ph. D. Thesis*, Tamil Nadu Agricultural University, India.
- THIRUMURUGAN AND GOVINDAN, 2001, Effect of integrated nutrient management practices on growth of neem under wastelands conditions. *Journal of Non timber Forest Produce*, **8** (3-4): 223 – 226.
- THOMAS, R. C. AND MEAD, D. J., 1992, Uptake of nitrogen by *Pinus radiata* and retention with in the soil after applying 15 N- labeled urea at different frequencies. *Forest Ecology and Management* , **53**: 131-151.
- \*TORRES, S., MARQUEZ, O., HERNANDEZ, R. AND FRANCO, W., 1993, Initial growth response of teak to phosphorus in the western planis of Venezuela. *Turrialba*, **43** (2): 113-118.

- VERICUMBE, I. AND OKALI, D. U., 1985, The effect of coppiced teak regrowth on soil in teak maize agroforestry. *Forest Ecology and Management*, **12** (1): 37- 41.
- WATANABLE, H., SAHUNALU, P. AND KHEMNARK, C., 1988, Combination of trees and crops in the taungya method as applied in Thailand. *Agroforestry syStems*, **6** (2): 169-177.
- \*WHITE, K. J., 1991, Teak some aspect of research and development. RAPA Publication, Food and Agriculture Organisation, Bangkok. pp, 1770.
- WHITE, K. J. AND CAMERON, A. L., 1967, Silviculture techniques, New Guinea Forest Platation Depatment, Papue New Guinea.
- WOJTKOWSKI, P. A., BROSTER, G. H. AND CUBBAGE, F. W., 1988, Using multiple objective linear programming to evaluate multiparticipant agroforestry systems. *Agroforestry Systems*, **7**(2): 185-195.
- YOSHIDA, S., FORNO, D. A., COCK, J. H. AND GOMEZ, K. A., 1971, Laboratory manual for physiological studies of rice. *International Rice Research Institute*, Manila, Phillippins, pp. 9-18.

---

\* Originals are not seen