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# Evaluation Growth and Yield of Wheat Varieties under *Ceiba pentandra* (L) Based Agrisilviculture System

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**Abstract** A field experiment was conducted at Indira Gandhi Agricultural University, Raipur Chattisgarh India to evaluate the growth and yield of wheat varieties under *Ceiba pentandra* (L.) Gaertn based on agrisilviculture system. The experiment consisted of 76 treatments combination of three tree spacing treatments (4×4m, 4×6m and 4×8m), four wheat varieties ( Sujata, GW-173, GW-273 and HD-2004) , two pruning regime, three distances (0.5 to 1.0 m, 1.0 to 3.0 m and >3.0 m) and four control plots (for each wheat variety). The experiment was laid out in a factorial randomized block design and it was replicated four times. After 9 years, Growth parameter of *Ceiba* tree stands revealed that the tree height, diameter at breast height, crown width and length, Number of pod tree$^{-1}$, Pod length, seed and floss yield decreased numerically from the lower tree density to higher density. Growth and yields were significantly higher in sole wheat than in wheat grown with *C. pentandra*. Shoot length in wheat decreased by 4.5-17.1%, while root length decreased by 29.8-35.9% at 60 days after sowing. The leaf area index of wheat did not exhibit any significant variation, but photo synthetically active radiation (PAR) interception was significantly higher in sole wheat and wheat intercrops under 4×8m spacing. The grain yield ranged from 24.0 to 29.1q/ha, Grain yield was highest in HD-2004 variety. The order of yield reduction in different verities was HD-2004 (34.5 %)>GW-173 (17.6 %)> Sujata (14.5%) when compared with HD-2004 variety. Higher grain yield (28.7 q/ha) was obtained in 4x8m tree spacing , while in other two tree spacings the grain yield was ( 25.40 q/ha) in 4x6m and (24.90 q/ha ) 4x4m spaicng. Growth parameters and Grain yield also varied with distance from the tree base.

**Keywords** Agrisilviculture System, *Ceiba pentandra,* Leaf Area Index , Pruning, Wheat, Yield

## 1. Introduction

Almost 175 m ha of land is subjected to several land degradation processes in India. The productivity of many fertile lands has substantially declined during past few decades. Presently, almost 100 m ha is lying as degraded wasteland, of which more than 70 % is carbon degraded Rastogi et al [21]. These soils have relatively high potential for accumulating organic carbon in vegetation and in soil. Therefore, there is need to integrate trees on marginal and fallow crop lands to ensure soil conservation, building organic matter and efficient nutrient cycling. In the light of both economic and ecological problems, there is growing concern about the sustainability of woody perennial based land use practices under such condition diversified farming like agroforestry becomes paramount importance. Agroforestry is a blend of agriculture and forestry, agroforestry is an interdisciplinary multisector approach and land use. Its prime objectives is overall optimization and to protect the environmental and maintain the ecological integrity. Agroforestry is a tree based land use management systems could also provide both ecological and economic benefits to local and global communities. Many different agroforestry practices have been identified world over [26]. Among agroforestry system agrisilviculture is one such system where agricultural crops are grown in association with trees. Choice of tree species and management play an important role in success of agrisilviculture system, where it is targeted to maximize complimentary and minimize competitiveness interactions between trees and crops. Emphasis is given to use fast growing multipurpose trees with desirable growth characters that could be compatible with crops and provide maximum benefits in quickest possible time. *Ceiba pentandra* (L) grows in dry, humid tropics. *C. pentandra* is a fast growing multipurpose tree and proved as one among the promising species for agroforestry practices [17,19]. It's commonly known as silk cotton tree distributed in south and central India up to an elevation of 450 m. It is a moderate size deciduous tree and a full grown tree of 15 years produce floss yield about 2.7 to 4.0 kg tree$^{-1}$. The tree has straight bole, acute branching and deciduous nature and potential to produce high quality floss and seeds at early age made the species as an ideal choice of farmers to practice in agroforestry in different parts of south and central India including Chhattisgarh state. Great thrust is given to intensively practice the species under agroforestry and farm forestry programs in this state, where monocropping of rice is practiced in more than 80 percent area only in kharif and lands are kept fallow in rabi season. As part of crop diversification, the state government is encouraging farmers to adopt agroforestry practices in different agro climatic zones of Chhattisgarh. Wheat crop is one of the most important cereal crops of India not only in term of hectarage, but also in terms of its versatility for adoption under wide range of agroclimatic and crop growing situations. So there is need to further increase area and production to fulfill requirement of exploding population, maintenance of adequate buffer stock and meet out demand for processing industries. The present study carry out the evaluation growth and yield of wheat varieties in a *Ceiba pentandra* based agrisilviculture system.

## 2. Materials and Methods

The experiment was conducted in the fields of Department of Forestry, Indira Gandhi Agricultural University, Raipur Chattisgarh India (21.76 $^{0}$N latitude; 81.36$^{0}$E longitude; 289 m asl) the studies were done on Nine-year-old *Ceiba pentandra* (L.) Gaertn. Trees planted at three spacing, viz, 4x4m, 4x6m and 4x8m. Four wheat varieties namely (Sujata, GW-173, GW-273 and HD-2004) were sown as intercrop in the first week of December. Before wheat sowing half of the trees in all spacing were pruned up to 25 % crown height, while reaming half were kept unpruned. Plots of the size 64 sq. m in 4x4m, 4x6m and 4x8m spacing were demarcated with in agrisilviculture system and in an area without trees which served as control plots for growing sole wheat varieties. Wheat varieties were sown in these plots in a randomized block design with four replications. Wheat varieties sown in plots without trees served as control plots. Seed rate of 125 kg/ha was applied by maintain a distance of 25 cm between the rows and 5 cm plant to plant. Recommended fertilizer dose of Nitrogen (urea)@120 kg/ha, phosphorus (SSP) @60 kg/ha, potassium (MOP)@ 40 kg/ha were applied for the wheat varieties viz, Sujata , GW-173, GW-273 and HD-2004. Urea was applied in two splits, half as basal dose at the time of sowing and remaining half 30 days after sowing in the form of top dressing. In order to study growth and yield of wheat crop, observations were taken at three distances from the tree base ie., 0.5 to 1.0 m, 1.0 to 3.0 m and >3.0 m . In all there were 76 treatments (3 tree spacing x 4 varieties x 2 pruning x 3 distances) and 4 control plots (for each wheat variety). Wheat population was recorded 30 days after sowing, plant height (shoot length) at 30 and 90 days of sowing and number of tillers at 60 days of sowing. Biomass (shoot and root) was measured at 30 and 90 days after sowing. Leaf area Index (LAI) and Photosynthetically active radiation (PAR) were measured using LI 2000 and Line quantum sensor (LI-191 SA LI-COR Inc, Lincoln , USA ) at 60 and 90 days of sowing. The observations were done in each plot with in a quadrate randomly at three places in sole wheat. In agrisilviculture the three random observations with quadrate were taken at three distances ranging from 0.5 to 1 m, 1.0 to 3.0 m and >3.0 m. from the main trunk. Number of effective tillers, Spike length, grains per spike, Test weight (1000 grain dry weight), grain and straw yield were measured at the time of wheat harvesting (after 120 days). The harvest index was calculated for each treatment by dividing the grain yield with the respective biological yield (Grain and straw) and converting in to percentage values. Before sowing of wheat crop, tree growth characters, viz, total height, clean bole height, diameter at breast height, crown length and width, LAI, PAR and at harvesting pod diameter, number of pod per tree , pod length, seed and floss yield of *C. pentandra* in different spacings were estimated. Crop parameters were analyzed statistically using analysis of variance for factorial randomized block design (tree factor). Simple randomized block design was used for analysis of tree parameters. The significance was tested for all the parameters at 5 % level. All statistical analysis were done using MSTATC programme (Version 1.41)

## 3. Results and Discussion

### 3.1. Growth of Wheat Crop in Agrisilviculture System

In agrisilviculture system the important factor that influences the crop productivity is the tree spacing. The population of wheat crop was significantly higher under wide compared to narrow tree spacing in agrisilviculture system. It varied from 198.3 to 254.1 m$^{2}$. Sole wheat recorded the highest plant population in comparison to intercrop under 4x4 m and 4x6 m tree spacing, while it was statically at par with 4 x 8 m treatment. The wheat population had reduced by 23 % in 4x4m, 15 % in 4x6m and 2.5 % in 4x8m tree spacing when compared to sole crop (Table 1). A significantly higher population was observed under pruned as compared to unpruned stands of *C. pentandra*. Among four wheat varieties, the highest plant population was found in HD-2004 variety fallowed by GW-273, GW-173 and Sujata. All these varieties showed significantly higher population in sole crop as compared to agrisilivculture system. The population of wheat gradually increased with increase in distance from the tree bole. The highest population was recorded at > 3m distance from the tree base. Wheat population was reduced by 9.9 % ,14.3 % and 17 % at >3 m , 1 to 3 m and 0.5 to 1m distance respectively from tree base compared to sole crop. Sharma et al. [22] observed that the reduction in plant population of wheat crop due to Poplar at 0 – 3 m distances from tree line was 34.2 % over control and this reduction was less with increasing distances from the tree line.

**Table 1.** Variation in morphological characters of wheat varieties grown under different spacings of *Ceiba pentandra*

| Treatment | Plant population/$m^2$ | No.of tillers/$m^2$ | Shoot length (cm) | | Root length (cm) | | Shoot Biomass (g/plant) | | Root Biomass (g/plant) | | Leaf area index | | PAR µ mol $m^2s^1$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 30 DAS | 90 DAS | 30 DAS | 90 DAS | 30 DAS | 90 DAS | 30 DAS | 90 DAS | 60 DAS | 90 DAS | 60 DAS | 90 DAS |
| *Tree Spacing* | | | | | | | | | | | | | | |
| 4x4m | 198.3 | 362.6 | 36.4 | 82.0 | 5.6 | 7.0 | 0.428 | 3.8 | 0.034 | 0.65 | 1.93 | 1.97 | 1403.3 | 1105.3 |
| 4x6m | 221.3 | 387.8 | 38.0 | 92.2 | 6.4 | 7.7 | 0.446 | 4.0 | 0.037 | 0.66 | 2.05 | 1.89 | 1403.3 | 1080.8 |
| 4x8m | 254.1 | 402.2 | 40.2 | 92.9 | 6.5 | 8.1 | 0.449 | 4.2 | 0.038 | 0.67 | 1.90 | 1.83 | 1403.4 | 1140.2 |
| CD at 5 % | 41.44 | 37.10 | 3.06 | 7.51 | 0.2 | 0.88 | NS | 0.18 | 0.00 | NS | 0.08 | NS | NS | NS |
| Control | 260.8 | 425.0 | 37.1 | 98.3 | 7.6 | 10.0 | 0.450 | 2.8 | 0.092 | 0.66 | 2.86 | 3.05 | 1449.3 | 1465.3 |
| C.D at 5 % | NS | NS | 3.33 | 1.85 | 0.42 | 0.78 | 0.00 | 0.06 | 0.006 | 0.01 | 0.16 | NS | 64.46 | 75.52 |
| *Pruning regime* | | | | | | | | | | | | | | |
| Pruned | 197.3 | 372.8 | 38.2 | 87.8 | 5.9 | 7.2 | 0.441 | 4.05 | 0.036 | 0.66 | 1.97 | 1.96 | 1396.8 | 1068.9 |
| Unpruned | 251.8 | 395.6 | 38.3 | 90.3 | 6.5 | 8.0 | 0.441 | 4.07 | 0.037 | 0.66 | 1.95 | 1.83 | 1409.9 | 1148.6 |
| CD at 5 % | 17.69 | 55.37 | NS | NS | 0.49 | 2.13 | NS | NS | NS | NS | NS | NS | NS | NS |
| *Variety* | | | | | | | | | | | | | | |
| Sujata | 219.2 | 381.6 | 40.9 | 106.3 | 5.2 | 6.7 | 0.445 | 4.12 | 0.038 | 0.68 | 1.86 | 1.76 | 1066.6 | 1066.6 |
| GW-173 | 220.3 | 376.4 | 33.6 | 72.8 | 5.9 | 7.2 | 0.414 | 3.87 | 0.034 | 0.64 | 1.98 | 1.95 | 1113.0 | 1113.0 |
| GW-273 | 229.0 | 379.6 | 38.0 | 76.2 | 7.2 | 8.8 | 0.417 | 3.85 | 0.035 | 0.62 | 2.13 | 2.06 | 1121.0 | 1121.0 |
| HD-2004 | 229.6 | 399.3 | 40.3 | 100.8 | 6.6 | 7.7 | 0.488 | 4.38 | 0.039 | 0.64 | 1.87 | 1.81 | 1134.0 | 1134.0 |
| C.D at 5 % | 3.50 | 10.86 | 8.41 | 1.85 | 0.11 | 0.20 | NS | 0.13 | 0.05 | NS | 0.10 | 0.94 | 16.41 | 16.41 |
| *Distance* | | | | | | | | | | | | | | |
| 0.5 to 1 m | 214.9 | 371.9 | 36.9 | 86.0 | 5.8 | 7.0 | 0.424 | 3.6 | 0.031 | 0.61 | 1.93 | 1.83 | 1106.5 | 1106.5 |
| 1to 3 m | 223.8 | 384.9 | 38.0 | 89.2 | 6.2 | 7.5 | 0.452 | 4.1 | 0.037 | .0.66 | 1.94 | 1.83 | 1109.6 | 1104.6 |
| >3 m | 234.9 | 396.4 | 39.8 | 91.9 | 6.6 | 6.3 | 0.447 | 4.3 | 0.041 | 0.70 | 2.02 | 2.95 | 1210.2 | 1210.2 |
| CD at 5 % | 3.42 | 9.40 | 1.15 | 1.73 | 0.09 | 0.17 | NS | NS | 0.005 | NS | 0.09 | 0.08 | 14.21 | 14.21 |

Number of tiller of wheat was significantly influenced by tree spacings, pruning regimes, varieties and distance from trees. It increased with an increase in tree spacing under agrisilviculture system. The number of tillers was 402.2 $m^2$ in 4 x8 m tree spacing, whereas it was only 387 $m^2$ under 4x6m spacing (Table 1). Almost tiller were reduced by 14 % under 4x4 m tree spacing compared to the sole crop. Number of tiller had decreased by 12.2 % in unpruned and 6.8 % in pruned tree in comparison to sole wheat the HD-2004 variety of wheat produced higher number of tillers in agrisilviculture system. Whereas other three varieties viz., GW-173, GW-273 and Sujata did not shows any significant variation. The number of tillers near tree trunk was significantly lower and it increase with increase in distance. Shoot length was significantly $p \leq 0.05$ effected by tree spacing , varieties and distances from tree bases at 30 and 90 days , however pruning did not show any significant effect almost similar in intercrop and sole crop at 30 days but was significantly higher in 90 days . Higher shoot length was observed in wheat grown under 4x8m and lower 4x4m at all growth stages. Among four wheat varieties the higher shoot length found in Sujata while lower in GW- 173 at 30 and 90 days of sowing. The shoot length increased with increase in distance from the tree base. It is evident from the data presented in (Table 1). Tree spacing; pruning, varieties and distance from the tree bases significantly influence the root length of wheat at 30 and 90 days. Length of roots was higher in sole crop than intercrop at 90 days. The root length varied significantly at different distances from the tree trunk. Shoot biomass was significantly $p \leq 0.05$ effected by tree spacing, varieties only at 90 days, while root biomass significantly affected at 30 days. Higher shoot and root biomass found in wheat grown as sole crop also in intercrop under 4x8 m tree spacing. The among four wheat varieties the higher shoot and root biomass was recorded in HD-2004 variety. Numerically a higher shoot and root biomass was recorded in wheat growing away from the tree bases.

Leaf area index in wheat crop was measured at 60 and 90 days. Tree spacing at 60 days both varieties and distance from the tree base at 60 and 90 days interval significantly $p \leq 0.05$ influenced the leaf area index .Pruning of trees did not show any significant effect on leaf area index of wheat. LAI of wheat crop was highest under sole crop than intercrop in all treatments. LAI increases with increase in tree spacing from 4x4m to 4x6m. Almost an increase of 79.29 %, 75.69 %, 49.64 % and 41.68 % of LAI was observed in Sujata, HD-2004, GW-173 and GW-273 varieties under sole crops compared to respective varieties under intercrop. LAI of crop was significantly higher in wheat grown away from the trees in comparison to wheat in proximity to the trees. PAR was significantly influenced by both wheat varieties and distances from tree base at 60 and 90 days. However it did not significantly affected by tree spacing and pruning treatments. Higher PAR was observed underneath the wheat canopies in sole crop compared to intercrop under different tree spacing (Table 1) Under agrisilviculture system, the maximum PAR (1467.5 $\mu$ mol $m^2 s^1$) was intercepted by GW-273 and HD-2004 varieties at 60 and 90 days respectively. The comparison between intercrop and sole wheat varieties showed PAR was almost 39.2 % higher in Sujata, 63.2 % in HD-2004, and 29.6 % in GW-273 and 23.2 % in GW-173 varieties at 90 days. Further the PAR levels also varied significantly in wheat plants at different distances from the tree trunk. Results from this study showed that shading significantly reduced the amount of PAR intercepted by the crop and consequently crop yield. Similar results were observed by Thakur and singh [30] in the case of *Morus alba* , in which 75 % canopy removal allowed more light transmission as compared to 0, 25 and 50 % canopy removal .In another study , light intensity was minimum in *Acacia auriculiformis* without pruning , but the intensity underwent a sharp rise on pruning Datta and Dhiman [5]. Several Studies have already proved that the light interception in tree-crop system is less as compared to open field [6,9] . Photosynthetic active radiation in crop was gradually increased with increasing distances from tree base in the present experiment. Many other studies have revealed the adverse effect on growth and yield of crop by tree component in the tree-crop system under different level of stresses and caused by growth behavior and age of tree [3,7,15,16,20]. Some previous studies showed that shading by Paulownia trees during reproductive growth of the wheat crop could significantly reduce the amount of incoming photo synthetically active radiation (PAR) available for the wheat crop from flowering to maturity, and possibly crop yield Lu et al [13]. The shading effect depends on the density and size of the tree crowns. Fangdong et al [8] showed that 9 year old paulownia trees in the 5 m by 20 m paulownia-wheat intercropping system reduced the incoming PAR above the crop canopy with in intercropping system by 17-25 % during grain filling.

### 3.2. Yield and its Attributes of Wheat Crop in Agrisilviculture System

Tree spacing, variety distances treatment had significantly influenced the effective tillers in the wheat, whereas as pruning did not show any significant effect on it. Except under 4 x4 m tree spacing, the average number of effective tillers was significantly higher in intercrop than sole crop. Significantly a higher number of effective tillers (321.0 $m^2$) were obtained in HD-2004 variety and it was lowest (277.1 $m^2$) in GW-273, which was statistically at par with GW-173 variety. Significantly higher effective tillers were observed in wheat plants growing away from tree bases > 3 m distances while it was lower near the tree bases. Spike length was significantly higher in sole than intercrop (Table 2). In agrisilviculture spike length was significantly higher 5.8 cm in 4x8m while it was lower in 4.8 cm in 4x4m tree spacing. Spike length has reduced by 44.4 %, 41.8 % and 36.5 % in 4x4m, 4x6m and 4x8m tree spacing respectively when compared to sole crop. The spike length was significantly lowered in wheat under unpruned compared to pruned trees. A higher 5.2 cm spike length was observed in HD-2004 while it was lowest 4.7 cm in GW-173 variety. Spike length was increased with increase in distance from the tree bases varied as 48. 1 % at 0.5 to 1 m, 45.3 % at 1 to 3 m and 34.5 % at > 3 m distances when compared to sole crop. Both variety and distances treatments significantly influenced the number of seed spike$^{-1}$, where as tree spacing and pruning treatments did not show any significant effect. Higher number seed spike$^{-1}$ was found under sole wheat than intercrop. Number of seed spike$^{-1}$ in the wheat ranged from 22.7 to 24.2 under different tree spacing. Among four wheat varieties HD-2004 recorded significantly higher number seed spike$^{-1}$ in both sole and intercropping compared to other varieties. Significantly higher number of seed spike$^{-1}$ 27.7 was found in wheat grown at > 3 m distance compared to 0.5 to 1m distance from tree trunk (Table 2).

Test weight of wheat was significantly influenced by pruning, variety and distance while tree spacing did not show any significant effect. It was higher 47.8 gm in sole crop compared to intercrop treatment. The lowest test weight was found in the crop grown under 4x4 m tree spacing, maximum test weight of 30.4 gm was found in HD-2004 variety in intercrop. Test weight was statically at par in Sujata and GW-173 varieties under intercrop. It was also higher 30.1 gm in wheat raised under pruned *Ceiba* plots compared to unpruned plots. Similarly it was higher in wheat grown away from the tree trunks and lowest near the tree base. A study by Chirko et al. [4] found that shading by the 11-year-old Paulownia trees in a Paulownia-wheat intercropping system reduced the crop yield by only 7% as a result of reduction in grain numbers per m$^2$, they also found that shading did not have significant influence on the dry weight per 1000 grains. It is possible that differences in tree sizes and wheat variety may contribute to the differences in effects of tree shading on wheat yield. Therefore a more comprehensive measurement of tree-crop competition for light aboveground and for water and nutrients below is required to understand better those differences Black and Ong [2]. All treatments including tree spacing, variety and distance significantly influenced the grain yield of wheat, while tree pruning did not exert any significantly effect. Mean yield was significantly higher in sole crop 33.7 qha$^{-1}$ compared to intercrop wheat. The grain yield increased with an increase in tree spacing. It ranged from 24.9 to 28.7 qha$^{-1}$. Grain yield has reduced by 26 %, 24.6 % and 14.8 % in 4x4m, 4x6m and 4x8m tree spacing respectively when compared to sole crop. Significantly a higher grain yield 29.1 qha$^{-1}$ of wheat was observed in HD-2004 variety fallowed by Sujata (26.4 qha$^{-1}$), Gw-273 (24.1 qha$^{-1}$). The reduction of grain yield of wheat varieties in agrisilviculture system compared to their sole crops was fallowed the order 37 % in Sujata, 18.3 % in HD-2004, 14.9 % in Gw-173 and 14.3 % in Gw-273. Grain yield of wheat reduced near to tree bases and it gradually increased with an increase in distance from the trees. Grain yield had reduced by 34 %, 23.7 % and 13.9 % at 0.5 to 1, 1 to 3 m and >3 m. distance respectively compared to sole crop. The grain yield is generally reduced under the tree shade, the reduction of grain yield under different agrisilviculture systems was in conformity with the findings of [23,25]. Wahua and Miller [31], has also recorded poor performance of soybean crop under tree species. The studies of Khybri et al [11] on tree crop interaction under *Grewia optiva*, *Morus alba* and *Eucalyptus* hybrid with rice and wheat cropping systems showed that all tree species had adverse effects on crop yield, where as wheat product mainly affected by *G.optiva* . The distance of tree from the crop significantly influenced the crop yield particularly up to 5 m and there was 39 % reduction in crop yield up to 1m, 33 % from 1-2 m , 25 % from 2-3 m and 12 % from 3 -5 m distance . It was observed that agriculture crops yield increased with an increase of crop distance from the tree. Further it was also reported that in agroforestry system the productivity was improved as the distance from the tree was increased Dhyani et al [7]. Overall, there is slight reduction in the agricultural yield in agrisilviculture system due to completion for light water and nutrients among trees and agricultural crops. The study from Newaj et al [14] showed that the grain yield of pure crop was higher than that from the tree crop systems. The wheat yield was affected by the presence of trees intercrop yield was also influenced by the proximity of trees. It was lower near the tree and it incresed as the distance increased from tree. Overall the reduction in the yield of intercrops due to presence of trees may be attributed to differential patterns of canopy spread resulting in variation in light interception (shade effects) and competition of the tree roots for nutrients and moisture. These results are in confirmation with the findings of Shrama et al [24]. Wheat grain yield of the four varieties tested revealed significant inter-varietal and intra-environmental differences. Variety HD-2004 performed the best followed by Sujata, GW-273 and GW-173 under *Ceiba* plantation. The yield of wheat varieties in the agrisilviculture system were found to be statistically significant ($P<0.05$). Variation in wheat yield under *Ceiba* may be attributed to inter-varietal differences (genetic) in respect of response variety to shade and stress of nutrient and moisture caused by trees Singh et al.,[27]. The straw yield of wheat was also affected significantly by the different varieties. The maximum straw yield was recorded in varieties, HD-2004 and Sujata as compared to dwarf varieties GW- 173 and GW-273. As the vegetative growth was maximum in HD-2004 during crop growth period, hence the straw yield was found to be maximum in variety. Straw yield followed the same pattern as grain yield. Tree spacing, varieties and distances treatments showed significant effect on straw yield of wheat where as pruning did not show any significant influence on this parameter, mean yield of straw was higher 44.9 qha$^{-1}$ in sole crop compared to different treatment of intercrop. It was 43.5 qha$^{-1}$ in 4x8 m, 40.0 in 4x6m and 39.1 qha$^{-1}$ 4x4m tree spacing. Among the different varieties of wheat , the straw yield reduced 12.2 % , 9.8 % and 2.6 % at 0.5 to 1 , 1 to 3 m and >3 m. distance respectively compared intercrop (Table 2). Harvest index was also significantly influenced by tree spacing variety and distance treatment, while pruning did not show any significant effect. It was highest in sole crop compared to all treatments of intercrop. In agrisilviculture Harvest index was highest 39.0 in 4x8m where as it was lowest in 36.6 % in 4x4m tree spacing. It reduced by 13 % in 4x4m , 9.8 % 4x 6 m and 9 % in 4 x 8 m where compared to sole crop . Among wheat varieties HD-2004 had highest harvest index 39.8 % while lowest in 37.6 % GW-273 variety. Highest Harvest index was found at>3m distance and lowest 0.5 to 1 m distance from tree base.

**Table 2.** Yield attributes of wheat varieties grown under *Ceiba pentandra* based agrisilviculture system

| Treatment | Number of effective tiller ($m^2$) | Length of spike$^{-1}$ (cm) | Number of seed (spike$^{-1}$) | Test weight (g) | Grain yield (q $ha^{-1}$) | Straw yield (q $ha^{-1}$) | Harvest Index (%) |
|---|---|---|---|---|---|---|---|
| *Tree Spacing* | | | | | | | |
| 4 x 4 m | 266.0 | 4.8 | 22.7 | 29.1 | 24.9 | 39.1 | 36.6 |
| 4 x 6 m | 292.4 | 5.2 | 23.3 | 29.7 | 25.4 | 40.0 | 38.8 |
| 4 x 8 m | 314.0 | 5.8 | 24.2 | 29.7 | 28.7 | 43.5 | 39.0 |
| CD at 5 % | 52.03 | 0.30 | NS | NS | 2.76 | 0.26 | 0.02 |
| Control | 279.3 | 8.7 | 36.4 | 46.3 | 33.7 | 44.9 | 42.6 |
| CD at 5 % | 15.33 | 0.40 | 1.94 | 2.1 | 3.90 | 4.39 | 2.25 |
| *Pruning regimes* | | | | | | | |
| Unpruned | 286.6 | 4.5 | 22.3 | 28.9 | 24.8 | 38.2 | 39.5 |
| Pruned | 294.9 | 5.6 | 24.5 | 30.1 | 26.5 | 38.5 | 41.5 |
| CD at 5 % | NS | 1.052 | NS | 3.01 | NS | NS | NS |
| *Variety* | | | | | | | |
| Sujata | 289.8 | 5.0 | 23.3 | 29.6 | 26.4 | 41.5 | 38.5 |
| GW-173 | 275.3 | 4.7 | 23.1 | 29.1 | 23.1 | 39.2 | 37.8 |
| GW-273 | 277.1 | 4.9 | 22.4 | 28.9 | 24.0 | 39.7 | 37.6 |
| HD-2004 | 321.0 | 5.2 | 24.9 | 30.4 | 29.1 | 44.5 | 39.4 |
| CD at 5 % | 2.39 | 0.24 | 0.93 | 0.76 | 0.66 | 0.65 | 0.95 |
| *Distance* | | | | | | | |
| 1 m | 283.0 | 4.5 | 18.7 | 25.9 | 22.2 | 39.4 | 36.4 |
| 1to 3 m | 239.5 | 4.7 | 23.9 | 28.3 | 25.7 | 40.5 | 38.7 |
| >3 m | 299.9 | 5.7 | 27.7 | 34.3 | 29.0 | 43.7 | 39.8 |
| CD at 5 % | 1.20 | 0.02 | 0.81 | 0.66 | 0.97 | 1.05 | 0.82 |

**Table 3.** Growth and yield of *Ceiba pentandra* in different tree spacing and pruning regimes in agrisilviculture system

| Treatment | DBH (cm) | Height (m) | Crown length (m) | Crown Width (m) | Leaf area index | PAR µ mol $m^2s^1$ | No. of pod /tree | Pod Diameter cm | Pod Length cm | Seed yield q/ha | Floss Yield q/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Tree Spacing* | | | | | | | | | | | |
| 4 x 4 m | 16.56 | 8.29 | 4.18 | 3.54 | 3.36 | 1208.1 | 190.2 | 5.23 | 13.5 | 9.62 | 7.62 |
| 4 x 6 m | 16.28 | 7.49 | 3.85 | 3.98 | 2.84 | 1224.6 | 157.0 | 5.01 | 15.2 | 7.62 | 3.59 |
| 4 x 8 m | 17.04 | 7.55 | 4.63 | 5.22 | 2.9 | 1239.6 | 140.6 | 4.86 | 14.0 | 5.37 | 2.75 |
| CD at 5% | NS | 0.76 | 0.74 | 0.45 | 0.36 | NS | 6.55 | 0.08 | 0.51 | 6.51 | 3.54 |
| *Pruning regimes* | | | | | | | | | | | |
| Unpruned | 17.60 | 8.02 | 4.98 | 4.40 | 3.05 | 1173.0 | 181.9 | 5.41 | 13.6 | 9.91 | 6.98 |
| Pruned | 15.65 | 4.09 | 3.46 | 4.10 | 3.03 | 1275.2 | 143.3 | 4.67 | 14.8 | 6.63 | 3.59 |
| CD at 5% | 1.27 | 0.41 | 0.61 | NS | NS | 45.38 | 5.35 | 0.07 | 0.42 | 5.32 | 4.07 |

### 3.3. Growth and Yield *Ceiba Pentandra*

In the present study, the three planting spacing of *C. pentandra* showed variability with respect to crown closure. The crown closure was seen in the 4x4 m spacing only, indicating that the initial rate of growth in trees was same. The narrow spacing is good in early stages because of high total volume accumulation, but narrow spacing usually restrains the growth of individual's trees. Also the narrow spacing leads to competition for resources (light, nutrients, and water). In the present studies although the above ground competition was not evident (as growth rate was same in three spacing), there seems to be below ground competition. Growth in the tree stands of *C. pentandra* revealed that the tree height, clean bole height, diameter at breast height and crown width and length decreased numerically from the lower tree density to higher density (Table 3). Total tree height, crown length and crown width were significantly influenced by different tree densities of *C.pentandra* while none of the other tree growth parameters show any significant variations. Swamy et al [29] also reported non significant variation in growth character due to different tree densities in the four year old stands *Gemelina arborea* . Both tree heights was higher in dense (4x 4 m) compared to open 4x8m stands. This may be due to less competition among the widely spaced tree especially for light, where inadequate lights conditions provide trees to grow taller in dense stands. The ability of tree to grow taller in dense stands was evident and confirmed with findings of [10,17]. Ajit et al [1] observed that height of trees was significantly increased in high density (800 and 400 tree $ha^{-1}$) compared to low density (200 tree $ha^{-1}$) in agrisilviculture stands of *Hardwickia binnata* . DBH was significantly affected by pruning, while total tree height by tree spacing treatment. Pruning had not any significant effect on tree height, while tree spacing did not exhibit any significance influence on DBH. In contrary to height growth, diameter at breast height (DBH) was higher in tree growing under wider spacing while it decreased in narrow tree spacing of *C. pentandra.* This is attributed to lower competition for resources among tree planted in wide spacing compared to narrow tree spacing. The other growth parameter like crown width and crown length were also higher widely spread trees. Sufficient space for crown spread and minimum competition for light increased the growth and proliferation crown in tree under wide spacing whereas the insufficient might have restricted crown growth in narrow tree spacing. These findings are line with Puri et al [16] . Tree spacing showed significant affect both crown length and its width. However pruning treatment had significantly influence the crown length but it did not show any effect on the crown width. Both parameters were significantly higher in 4 x 8 m compared to other tree spacing. Significantly higher crown length 4.9 cm was attained by unpruned stands, where it was almost reduced 30 % in pruned trees. Leaf area index varied significantly in different tree densities while pruning did not show any influence. LAI was significantly higher in narrow tree spacing to wide tree spacing. A reduction of 15 % LAI was observed in 4x6m and 13.6 % in 4x8m stands as compared to 4x4m stands. Higher PAR was observed in 4x8 m and it gradually decreased with decrease in different tree spacing. It ranged from 1208 to 1239 µ mol $m^2s^1$ in different tree spacing. LAI of *C.pentandra* was significantly higher in tree under narrow compare to wide tree spacing. It reduced by 15 % in 4x6m and 13.6 % 4x8m compared to 4x4m spacing. In contary PAR was significantly higher in wide compared to narrow tree spacing. These findings are similar to reports earlier worker [18,28] . Swamy et al [29] reported significantly higher LAI in stands planted at closer spacing ( 2x2m and 2x3m ) compared to stands at wide spacing (2x4m and 2x5m) in *Gemelina arborea* whereas PAR was higher at wide spacing. The study also confirmed the inverse relationship between LAI and PAR which was reported in the past Puri et al [18]. A pod $tree^{-1}$ was significantly was higher in 4 x4 m and it decreased with an increase in tree spcing. Due to pruning almost 21 % of pods $tree^{-1}$ had reduced. Pod diameter was highest 5.2 cm in 4x4m tree spacing, while pod length was maximum 15.2 cm in 4 x 6 m tree spacing. Pod diameter 5.4 cm was highest in unpruned plot whereas pod length was maximum 14.8 cm in pruned plot. Floss and seed yield ranged from 2.75 to 7.62 q $ha^{-1}$ and seed yield 5.37 to 9.62 q $ha^{-1}$ in different tree spacing of *Ceiba* .Highest floss and seed yield was obtained in 4x4m while lowest in 4 x 8 m spacing. Seed yield reduced by 63 % and 52 % and floss yield by 44 % and 20 % in 4 x 8 m and 4 x 6 m tree spacing. This is evident from the fact that the trees growing under narrow spacing (4x4m) flowered heavily which ultimately produced more pods and floss .Reduction of 48 % in floss and 33 % seed yield in pruned trees. Floss and seed yield were significantly highest in 4 x4 m spacing trees while both were lowest in 4 x 8 m spacing seed yield reduced by 63 % and 52 % and floss yield by 44 % and 20 % in 4x8m and 4x6m tree spacing respectively compared to 4x4m tree spacing. Floss yield was lower in range compared to that reported Lamprecht, [12] where it was 2.7 to 4 Kg $tree^{-1}$. The difference in yield might to due to the different in age of stands. The lower floss yield in present study might be attributed to lower age of the stand (Nine year old).

# 4. Conclusions

This investigation indicates that the wheat varieties respond differently under agrisilviculture practices and HD-2004 variety should be grown with *C.pentandra*. However, further studies are needed to screen various other cultivated crops of the region to find out compatible crops, which could be complementary in the system. Furthermore, there is a need to evolve wheat varieties suitable for inter cultivation in such a system as the trees matures and attains harvestable age. By combining suitable complementary variety along with tree farming the production level of both grain and timber can be sustained.

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