Differential response of pruning intensities in *Dalbergia sissoo Roxb.* on growth and yield of rice varieties under agri-silviculture system

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(AGROFORESTRY)

By

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2017

CERTIFICATE - I

This is to certify that the thesis entitled ***"Differential response of pruning intensities in Dalbergia sissoo Roxb. on growth and yield of rice varieties under agri-silviculture system"*** *submitted in partial fulfilment of the requirement for the degree of* ***MASTER OF SCIENCE (Forestry) in Agroforestry*** *of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, is a record of the bonafide research work carried out by* ***Ms. Allana Francesca Marak,*** *under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.*

All the assistance and help received during the course of investigation has been acknowledged by her.

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ABBREVIATIONS

At the rate of	:	@
And others	:	*et al.,*
Centimeter	:	cm
Critical difference	:	CD
Days after sowing	:	DAS
Degree centigrade	:	^{0}C
Degree of freedom	:	df
Diameter at breast height	:	dbh
Fertilizer dose	:	FD
Figure	:	Fig
Gram	:	g
Harvest index	:	HI
Hectare	:	ha
Maximum	:	max
Meter	:	m
Minimum	:	Min
Millimeter	:	mm
Morning	:	Morn.
Namely	:	viz.
Nitrogen	:	N
Per hectare	:	ha^{-1}
Percentage	:	**%**
Phosphorus	:	P
Potassium	:	K
Quintal	:	q
Recommended dose	:	RD
Rupees	:	Rs.
Seed rate	:	SR
Standard error of means	:	SEm±
That is	:	i.e.

INTRODUCTION

India is the second most populated country in the world and their main livelihood is dependent on agriculture. The exponential growth in human and livestock population over the years coupled with declining production, soil erosion, declining cultivable land increased gaps between supply and demand for timber, fuel and fodder. The growing appetite for trees for fuel, fodder and timber for construction in both rural and urban areas has largely been responsible for much of the deforestation. There is a chronic deficiency of timber, fuelwood and fodder and a huge shortfall of basic needs besides an enormous damage to the resources, renewable as well as non-renewable on account of their abuse and overuse in India and other Southeast Asian countries.

India’s forests are under severe pressure for meeting growing demands for fuel, fodder, grazing, timber and non-timber forest products from an ever increasing human and livestock population and industrial demands. Approximately one fourth of the world’s poor and 90% of the poorest depend significantly on forests for their livelihoods (WHO, 2003; Mishra, 2011; Malhotra et al., 1991). The present forest area of the country *i.e.* 69.7 million ha. (23.82%) is not in a position to meet out the present demand of resources for small and large scale industry and forest products. To meet out the requirement of people, there was over-exploitation of natural resources in the country, which resulted in soil erosion, pollution, global warming, endanger flora and fauna. To maintain the ecological balance and natural resources one third area of the total geographical area of country must be under the vegetation and to maintain this ecological balance, tree area should be increased. The gap between supply and demand can be reduced through efficient management of natural resources. Since existing allocation to agriculture and forestry are inadequate to meet the demands for food, timber, fuel and other minor products, now is the right time to exercise option to convert low productive and less exploited land into a productive one by adopting agroforestry for diversification and sustainable biomass production.

In agroforestry, trees are grown along with crops. The main disadvantage in this is that the tree creates a shading effect on the crops, because of which the crops tend to give low yield. Light is the principal limiting factor for the growth of understory vegetation as the light penetration is decreased with the increased standing density of trees (Acciaresi *et al.*, 1994). However the yield of the crop can be increased by manipulating the tree canopy which can help the associated crop. Pruning reduces the tree canopy thereby facilitating more entry of light. It has become an essential practice for reducing both above and below ground competition with associated crops (Fownes and Anderson, 1991)

Agroforestry offers an economical and ecologically viable option for large scale diversification in agriculture on one hand and environmental amelioration on the other. The increasing population and rapid industrialization has increased pressure on the traditional forests for timber and other related wood products. Therefore, to save forests and meet the growing demands of wood, there is need for large scale plantations of fast growing tree species outside forests to make country self reliant in its timber requirements. Fast growing tree species with rotation of less than ten years like babul, eucalypts, leucaena etc. have gained preference due to their higher productivity and acceptability in the market.

Agroforestry can be defined as “an approach to land use that incorporates trees into farming systems, and allows for the production of trees and crops or livestock from the same piece of land in order to obtain economic, ecological, environmental and cultural benefits” (Thevathasan et al., 2004). Diversification of existing farming systems by developing suitable agroforestry models seems to be the need of the day to cope up with ever increasing demand for diversified products. Diversification in traditional crop rotation (rice-wheat) has been accorded a high priority in irrigated agro-ecosystem of North-western states of India due to several socio-economic and ecological problems i.e. insufficient storage space for rice and wheat produce, declining soil health, depleting underground water resources, indiscriminate use of agrochemicals, etc. It has high potential to simultaneously meet out various important aspects i.e. to protect and stabilize the ecosystem, produce high level of output of economic goods, provide employment, increased income and basic material to rural populations.

Farmers have enthusiastically adopted some of the agroforestry system such as agrihorticulture, agrisilviculture, hortiolericulture, silvipastoral and energy plantation in recent years. It provides an excellent opportunity for them to combine tree planting (fruit /fodder) with agricultural enterprises and also fuel/timber trees in their land.

In Madhya Pradesh, legume trees were found growing respectively for fuel, fodder and small timber purpose in both extensive grazing system and in association with field crop. *Dalbergia sissoo* has now emerged as very popular and commercially planted tree in agroforestry because of its quality timber production, deciduous in nature and nitrogen fixing tree. In trees, considerable amount of nutrients are incorporated into the soil through leaf litter fall and it's recycling which balance the nutrient reserve of the soil. *Dalbergia sissoo* is known to fix nitrogen symbiotically and substantial improvement occurs in the soil system due to enrichment of soil by addition of organic matter and nutrient content, which increases the agricultural production. Paddy is a staple crop of India and there are many varieties which perform well in the open conditions, but their productivity under shade condition is not known. Keeping above view in mind, an experiment entitled "Differential response of different pruning intensities in *Dalbergia sissoo* Roxb. on growth and yield of rice varieties under agri-silviculture system" is undertaken with the following objectives:

1. To find out the most appropriate pruning intensity for wood and grain production
2. To find out suitable variety of paddy under different pruning management
3. Find out the economic viability of the system

REVIEW OF LITERATURE

The present investigation deals with the growing of field crops under a well established tree plantation in agri-silviculture system. Agri-silviculture systems are biologically more complex than other means of using land; either through arable farming, fruit cultivation or forest farming. A common hypothesis strongly implied to the agroforestry systems is that integration of trees with annual crops increases the overall productivity and improves the physical as well as chemical properties of the soil. So, for the present study, **"Differential response of different pruning intensities of *Dalbergia sissoo* Roxb. on growth and yield of rice varieties under agri-silviculture system",** an attempt has been made to collect the available literature, which is being reviewed in this chapter under following heads:

2.1 Effect of crop on the morphological characters of tree growth.
2.2 Effect of trees on crop growth and yield of associated crops.
2.3 Effect of pruning
2.3.1 Pruning
2.3.2 Effect of pruning on tree growth
2.3.3 Effect of tree pruning on growth and yield of rice varieties.
2.3.4 Effect of tree pruning on grain yield of rice varieties.
2.4 Economics

2.1. Effect of crop on the morphological characters of tree growth

Incorporating trees into farming systems leads to greater prosperity and diversification at the farm level. Trees provide farmers with marketable products such as fuelwood, fodder, fiber, fruits and medicines; all of which earn extra income. No doubt trees surely offer economic and ecological advantages, but both the tree and the annual crop compete with each other for their share of light, space and nutrients, thereby affecting each other in some way or the other. The rate and extent to which biophysical resources are captured and utilized by the components of an agroforestry system are determined by the nature and intensity of interactions between the components. The net effect of these interactions is often determined by the influence of the tree component on the other component(s) and/or on the overall system, and is expressed in terms of such quantifiable responses as soil fertility changes, microclimate modification, resource (water, nutrients, and light) availability and utilization, pest and disease incidence, and allelopathy. The effect of microclimate (light, temperature including air and soil temperature, soil moisture, relative humidity and wind speed) is caused by shading of the trees on the understory crops. The canopy cover also affects the microclimate of the understory. Microclimate has positive effects on the agroforestry systems to conserve the soil, maintain the soil moisture, improve the yield of understory crops such as wheat, turmeric, rice etc. Microclimate also helps to improve the yields of trees (Tripathi et al., 2016). Increased productivity, improved soil fertility, nutrient cycling, soil conservation are the major positive effects of interactions and competition is the main negative effect of interaction.

Gill et al. (2008) reported that intercropping of lemon grass, turmeric, celery, coriander, fennel, fenugreek, mentha species and mustard with poplar trees increased the dbh and height of poplar tree.

Kaith et al. (2011) studied the effect of pruning intensities on apple cultivar in a private orchard at Rohru in Shimla district. Four pruning intensities were used as treatments in this study. The results revealed that in different pruning intensities the plant growth increased due to more vegetative growth. Lower yield recorded during the year 2007 might be partly due to alternate bearing habit of the apple and partly due to the weather conditions. The leaf nutrient status was also affected by the different pruning intensities. Leaf nitrogen and potassium contents increased with the increase in severity of pruning, whereas leaf calcium content was found to decrease.

Puri et al. (2015) conducted a field experiment at Indira Gandhi Agricultural University, Raipur, Chhattisgarh to evaluate the growth and yield of wheat varieties under *Ceiba pentandra* (L.) Gaertn based on agrisilviculture system. At the age of 9 years, growth parameter of *Ceiba* tree stands revealed that the tree height, diameter at breast height, crown width and length, number of pod per tree, pod length, seed and 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*.

Kaushal et al. (2017) initiated a study in eight runoff plots (25 x7.5 m) to study the impact of canopy management treatment in *Morus alba* on productivity and resource conservation on sloping land (>10%). Treatments *viz.,* coppicing, pollarding and lopping were carried out on existing trees of *Morus alba.* Each plot consisted of 15 numbers of trees. In one set of canopy management treatment, turmeric was raised as intercrop. The data revealed that intercropping of turmeric increased growth and biomass production in *Morus alba.* Maximum fuelwood (60.4 q ha^{-1}) and green leaf yield (48 q ha^{-1}) was recorded in Lopping + turmeric treatment. Average soil moisture (Oct-March) in 0-90 cm soil depth varied from 236.3 mm in cultivated fallow to 267.6 mm in pollarding treatment. Significant differences were also observed in fine root biomass.

2.2 Effect of trees on crop growth and yield of associated crops

The integration of trees and crops leads to complex interactions among the components at various bio-physical domains such as light, space, water, nutrients, etc. The complementary effects among these factors is the key to success in an agroforestry system. The modifications in micro-environment due to growing of trees, directly or indirectly, influence various vital physiological processes of the plants grown under tree canopy.

Chauhan et al. (2012) reported that the quantitative performance of wheat crop under 1-5 year old poplar plantations in irrigated agroecosystem was studied to ascertain the biological yield of tree and crop. Results revealed that growth and yield of wheat decreased significantly with increase in poplar age. The per cent reduction in net grain yield was 17% under one year old poplar plantation, which increased to 52.15% under five year old plantation.

Chauhan et al. (2013) evaluated an agri-horti-silvicultural model involving poplar (*Populus deltoides* Bartr. Ex Marsh.) as timber tree component, fruit trees and agronomic crops viz turmeric and moong obtaining the yield. Net photosynthesis, stomatal conductance and transpiration in both crops were higher in open areas than in shaded ones. Agronomic crops showed initially better performance under partial shade in yield and yield contributing parameters, and decreased as poplar canopy advanced in age. Changes in these parameters showed inverse relationship with canopy age and vice versa, with more yield reduction under fifth year old canopy followed by preceding years and control. The results of studies on the micro-climatic interaction and resultant effect on physiology, yield and economics of agronomic crops under poplar tree canopy are presented. The transpiration (E) rate of crops was lowest under shade conditions irrespective of the crop used in the experiment, leading to more water use efficiency in the shade conditions than in open. There was gradual reduction in crop yield with advancement of age, but the economic benefits of intercropping were two to three times higher than traditional crop rotation. It is suggested that, to minimize resource competition and improve physiological processes of crops, canopy management is essential to ensure better yield under poplar-based agri-horti-silvicultural system.

Mondal et al. (2013) conducted an experiment to investigate the effect of alley widths of *Gliricidia sepium* and different nitrogen levels on yield of Aus rice (BR24). The experiment was laid out in a split-plot design with three replications. Three alley widths - 3.0m, 4.5m, and 6.0m and a control without trees, were compared under five N doses 0, 18.75, 37.5, 56.25 and 75 kg ha^{-1}. *G. sepium* species gave the highest (20.24 t ha^{-1}) pruned materials from closer alley width (3m). The highest grain yield (3.54 t ha^{-1}) of rice was obtained at 75 kg N from urea and pruned materials (PM) in 4.5 m alley width. The study suggested that *G. sepium* can contribute to increased rice yield and increased N use efficiency.

Mishra and Swamy (2014) studied the productivity of wheat under five promising clones (G3, G48, 65/27, D121 and S7C1) of *Populus deltoides* in agrisilviculture system. Grain yield of wheat varied from 25.5 to 36.6 q ha^{-1} and straw yield from 34.9 to 60.7 q ha^{-1}. The yields were highest in sole wheat and reduced under poplar clones from 15 to 30.3% and from 22.7 to 42.5%, respectively. The reduction of wheat yields in different clones was in the order: G3<S7C1<D121<65/27<G48. The total nutrient uptake varied from 34.17 to 66.09 kg N ha^{-1}, 12.04 to 25.32 kg P ha^{-1} and 35.6 to 67.6 kg K ha^{-1}. After 6 years of poplar planting, N in soil increased by 14.9-24.1%, P by 17.2- 23.3% and K by 3.1-5.1% at 0-20 cm depth. The study suggested adopting lopping, root hoeing and nutrient management practices in poplar clones G48 and 65/27 to minimize yield losses in wheat under these clones.

Pardeep (2014) carried out a study at Agroforestry Research Farm, Chaudhary Charan Singh Haryana Agricultural University, Hisar to study the effect of different spacings of poplar (*Populus deltoides*) on the performance of some winter spices. The investigation was carried out with two objectives - to evaluate the performance of the different winter spices under different spacings of poplar and to work out the economics of the system. With the above objectives, the investigation was carried out with planting four spice crops, i.e. methi (*Trigonella foenum-graecum*), fennel (*Foeniculum vulgare*), coriander (*Coriandrum sativum*) and ajwan (*Trachyspermum ammi*) under three spacings of poplar, i.e. 5 × 4 m, 10 × 2 m and 18 × 2 m and control (without poplar). Yield of crops increased with increasing spacing of poplar, and minimum yield reduction was recorded in methi under poplar based agroforestry system with 18 × 2 m spacing. Based on experimental data, it can be concluded that methi (variety HM-33) should be planted in wider spacing i.e. 18 × 2 m for better yield in poplar agroforestry system.

Singh et al. (2014) studied the performance of wheat under poplar based system in Punjab. The farmers of this zone intercrop wheat along with poplar stands. Wheat performance data were collected from farmers fields with different population densities (i.e. 225, 250 and 300 plants/acre) and age (1, 2, 3 and 4 year old) of poplar. The results revealed that there was non-significant difference in number of tillers and ear length under 225 and 250 per acre population density; however, these parameters were significantly less under higher poplar density (300 plant/ acre). Test weight decreased significantly with increase in poplar population density. Poplar density of 225 plants per acre produced significantly higher grain yield (8.0 and 25.6 per cent more than at 250 and 300 plants/acre). The number of tillers and ear length were not affected up to two year age of poplar, while reduced significantly afterwards. Test weight reduced significantly with age of poplar trees, which leads to significant decrease in wheat grain yield with increase in age of poplar. Wheat yields in 2, 3 and 4 years old poplar were reduced by the margin of 9.9, 26.9 and 49.8 per cent as compared to one year old poplar. Poplar density of 225 and 250 plants/acre accrued equal or more DSH and DBH in three years as compared to population density of 300 plants/acre, in addition to higher wheat yield.

Sangwan et al. (2017) evaluated garlic crop for yield and ecophysiological behaviour under agri-horti-silvicultural model involving different combinations of fruit trees and poplar (*Poplar deltoids* Bartr. Ex Marsh.). Net photosynthesis, stomatal conductance and transpiration rate in garlic were recorded as higher in partial shading of pear × plum combination than in highly shaded area of poplar trees. Garlic showed better performance under partial shade in yield and yield contributing parameters, but decreased as canopy advanced with age. These parameters showed inverse relationship with canopy age and vice versa, with more yield reduction under sixth year old canopy followed by preceding years and control. The transpiration rate of garlic was lowest under shade conditions, leading to better water use efficiency in shade conditions than in open. It is suggested that to minimize resource competition and improve physiological processes of crops, canopy management is essential to ensure better yield under pear-poplar based agri-horti-silvicultural system.

2.3 Effect of pruning

2.3.1 Pruning

The performance of trees and crops in an agroforestry system primarily depends upon their relative ability to tap the resource pools of light, water and mineral nutrients. Resilience of a component to respond to sub-optimal level of resources at any growth stage in a tree crop system will stabilize or destabilize the tree-crop association which ultimately will influence the yield advantage of an agroforestry system.

Management of tree component in agroforestry systems at suitable age intervals is of great importance. The management entails maximizing the production of the desired products through minimizing competition for growth resources among the tree-crop components. Out of all management practices, pruning is most common and also of utmost importance. In pruning, the removal of some parts of a tree obviously reduces the competition ability of the tree, because of better light penetration to under storey crop and reduces the demand of moisture and nutrients. Tree pruning is a common management practice in agroforestry for mulching and reducing competition between the annual and perennial crop. The impact of pruning is related to the degree to which radiation interception by the crown is affected. On the other hand, faulty tree management techniques can lead not only to lower yields, but trees may also die; perhaps even the loss of entire plantation, because every tree species has different growth behaviour under different soil and climate.

2.3.2 Effects of pruning on tree growth

In agroforestry systems, trees and crops inevitably compete for light, nutrients and other resources. Pruning of the tree component is a powerful approach to regulate this competition (Frank and Eduardo, 2003). In agrisilviculture system, pruning facilitates penetration of light and alleviates shading of understorey crop while simultaneously increasing the merchantable value of the tree component. Pruning of trees has been extensively used in silvicultural management to improve timber quality and provide easy access into the stand for inspection. Impacts of pruning on tree growth and development depends not only on the amount of branches and leaves removed, but also on the tree size, growth habits, pruning seasons, intensity and pruning frequency.

Meena (2008) studied that in agrisilviculture system among different pruning intensities (no pruning, 25%, 50% and 75% pruning) of *Dalbergia sissoo*, significantly more tree height was recorded in 25% pruning (7.92 m) followed by no pruning (7.47 m) and 50% pruning (7.33 m) where 75% pruning recorded the lowest tree height.

Nayak et al. (2011) field experiment was conducted during 2010 *kharif* season under 12 years old *Dalbergia sissoo*. The treatment combinations involved five treatments viz., four pruning intensities (no pruning, 25%, 50%, 75% pruning) and one open (without tree, crop only). Results revealed that

25% pruning recorded highest dbh (19.91), cylindrical volume (124.12 m^3 ha) and stand biomass (95571.7 kg ha^{-1}). Total biomass production was higher in 25% pruning and lowest in 75% pruning. In *Dalbergia sissoo* based agrisilviculture system, 50% pruning recorded higher paddy yield in addition to biomass yield of woody component, which may be recommended under rainfed agro ecosystem.

Mehta et al. (2012) revealed that pruning of guava plant done thrice a year viz. March, May, October to 50% of shoot length, can be recommended for maximization of income from ultra-high density guava orchard with total yield per ha as 34.88 t ha^{-1} and 37.24 t ha^{-1} during 2009-10 and 2010-11, respectively.

Palsaniya et al. (2012) carried out an experiment consisting of five treatments viz., pasture + tree without pruning, 25%, 50%, and 75% canopy pruning and pure pasture in four year old *Albizia procera* based silvi-pastoral system. They observed significantly higher tree height (4.7m), dbh (9.6cm), under 75% canopy over other treatments. Unpruned and 25% pruning, recorded significantly higher canopy spread over 75%, the increase being 39% and 44%, respectively. Similarly, 75% canopy pruning also recorded higher dry leaf fodder (1t/ha), fuelwood (1.9t/ha) and total dry biomass (2.9t ha^{-1}) from *Albizia procera* over both 25% and 50% canopy pruning treatment.

Alvaraez et al. (2013) reported that pruning practices could potentially be used to obtain poles and firewood without a decrease in wood productivity. Results revealed that pruning could improve the shape in the short run and increase stem diameter in the long run.

David et al. (2013) observed that change in stand structure, crown architecture and tree nutrition can be used to alter absorbed photo synthetically active radiation and light-use efficiency, and improved inventions in Eucalyptus plantation management for solid-wood products.

Bisht et al. (2014) carried out a study in *Dalbergia sissoo* based agroforestry system raised on sodic land at Main Experiment Station (Forestry) of Narendra Deva University of Agriculture and Technology, Kumarganj, Faridabad. The investigated area was divided into five equal quadrates (20×25m size) within 0.25 ha area. Of these, four quadrates were chosen for trials of different intensities of lopping (25,50,75 and 100% lopping intensities) and one quadrate was treated as control (0% lopping intensity). Initial tree height across different lopping intensities ranged from 12.8-15.2m and dbh from 10.8-13.9cm. Across lopping intensities, tree growth increments were maximum in rainy season (tree height increment: 0.20-0.60m/season; dbh increment: 0.20-0.80cm/season), followed by summer season. Interestingly, there was a clear cut decrease in growth along increasing lopping intensity.

Erkan et al. (2016) studied the effect of pruning on diameter growth in *Pinus brutia*. For this purpose, three field experimental sites, each with different site qualities, were established in three different locations (i.e. Buk, Nebiler and Kursunlu in Turkey). Four different treatments were applied at each test site : 1) control, no pruning of branches, 2) pruning up to 25% of tree height, 3) pruning up to 50% of tree height, and 4) pruning up to 75% of tree height. The effects of pruning on DBH growth were observed over a period of 14 years. At Bük test site, which had the poorest site quality, only those specimens pruned up to 75% of tree height showed significant reduction in DBH growth compared to the control. However, at Nebiler and Kursunlu test sites, specimens pruned both up to 50% and 75% of tree height showed statistically significant decrease in dbh growth. To recover from pruning stress in terms of DBH growth rate, it took trees 6 years at the poorest test site and 4 years at the relatively better test sites. This indicates that site quality of plantation accounts for not only dbh growth differences between sites, but also recovery rate of trees from any disturbances. Results showed that for those trees pruned up to 75% of their height, total DBH growth was reduced by between 6.5% and 9.0% after 14 years, compared to the control at the test sites. No negative effect from pruning on dbh increment was observed in the first growing season. This may be due to earlier storage of nutrition in different parts of trees, thereby enabling them to compensate for the stress of crown reduction during the first growing season following pruning.

Kumar (2016) conducted an experiment in which turmeric was planted along with *Dalbergia sissoo* based agrisilviculture system. The trees were pruned under different pruning intensites viz., no pruning, 25%, 50%, 75% and open conditions. Different pruning intensities showed significant effect on tree dbh. 25% pruning recorded significantly higher dbh (24.6 cm) which was at par with no pruning (23.8 cm) and 50% pruning (22 cm). 75% pruning recorded significantly lower stem diameter at breast height (17.4 cm). Different level of date of planting showed no significant influence on dbh of *D. sissoo*. Different pruning intensity showed significant effect on canopy spread in N-S and E-W direction. No pruning recorded significantly higher canopy spread in both N-S (9.88 m) and E-W (9.95 m) directions, which was significantly superior to different pruning treatments. Among different pruning intensities, 25% pruning recorded significantly higher canopy spread in N-S (8.43 m) and E-W (8.61 m) direction, which was at par with 50% pruning (7.48 m) and (7.53 m). 75% pruning gave the lowest canopy spread in both N-S (6.41 m) and E-W (6.46 m) directions.

2.3.3 Effect of tree pruning on the growth and yield of rice varieties

A major problem of simultaneous agroforestry system is the competition between the annual and perennial crop. Pruning the above ground biomass was an effective way of controlling below grown growth (Peter and Lehmann., 2000). This can be used in intercropping systems to manage tree crop interactions. Shading by trees is believed to be responsible for poor yields of associated crops. This problem is more acute when the tree remains unpruned. Alley cropping agroforestry system has emerged as a sound technique, where tree canopies are periodically pruned to prevent shading of companion crops. A substantial improvement in crop yield in forestry systems was reported where tree prunings were used as mulch or as green manure (Roy et al., 2005).

In an agroforestry system, reduction in crop yields could be minimized by proper pruning of tree component. Light is the principal limiting factor for the growth of understory vegetation, as the light penetration decreases with the increased standing density of trees.

Islam et al. (2006) carried out a study to investigate the effect of pruning on the yield and yield attributes of rice grown under eight year old *Dalbergia sissoo* trees in Bangladesh. The trees were pruned severely, moderately, medium and lightly. Out of the four tree-rice associations, severely pruned trees gave the highest rice yield (3.63 t ha^{-1}) and lowest rice yield (2.70 t ha^{-1}) was produced by lightly pruned trees; whereas the control (crop only) produced the highest rice yield as compared to all orientations. Therefore, for tree-rice agroforestry system, tree species having light canopy is suitable since they allow easy penetration of sunlight, while tree of dense canopy requires heavy pruning, especially in the north-east orientation.

Dar (2007) studied in detail the effect of pruning in 5 and 6 years old *Albizia procera* on the performance of intercrops at Jhansi, Madhya Pradesh. He tried 50 and 70 per cent canopy pruning against no pruning and observed that the growth, yield and yield attributing characters of intercrops blackgram, greengram, mustard and wheat were significantly higher in 70 per cent pruning than 50 per cent canopy pruning and control (unpruned) during two years of study.

Thakur (2013a) conducted a study to find out the most appropriate pruning intensity for *Dalbergia sissoo* for maximum production of paddy under agrisilviculture system. Highest grain and straw yield of paddy was recorded under open condition (32.40 q ha^{-1} and 67.70 q ha^{-1} respectively), whereas no pruning recorded the lowest grain and straw yield (14.10q ha^{-1} and 35.50q ha^{-1} respectively). Among different pruning intensities, 75% pruning produced significantly maximum grain yield (27.10q ha^{-1}) and straw yield (58.90 ha^{-1}) followed by 50% and 25% pruning.

Patel (2015) carried out an experiment to study the effect of pruning on the growth parameters of paddy under *Dalbergia sissoo* agrisilviculture system. It is found that the growth parameters of rice (viz., plant height, tillers per m^2), were significantly varied due to the effect of different pruning treatments and agronomical management practices. It was also noted that all the growth parameters significantly increased with increasing pruning intensities in combination with 25% more nitrogen than the recommended doses. Among all the pruning treatments, open condition (only crop) showed superiority over all plant growth parameters relevant to most of the treatments at different growth intervals and at harvest. However, these parameters were at par with the 75% pruning while the minimum values of the growth parameters were observed under the 25% pruning. Under agronomical management practices 25% more nitrogen than the recommended dose of fertilizer showed superiority in all plant growth parameters over the recommended dose of fertilizer and seed rate which was at par with 25% more seed rate.

Yadav et al. (2015) carried out an experiment to determine the yield and yield attributes in Jatropha based agrisilviculture system in Tarai region, Uttarakhand. The study was carried out at Pantnagar. The experiment was laid out in factorial Randomized Block Design with twelve treatment combinations comprising four pruning height viz., no pruning**,** 50 cm height**,** 100 cm height**,** 150 cm height in Jatropha and three fertility levels viz., 50% of recommended dose of NPK (RDF)**,** 100% (120 kgN+60kg P2O5+40 kgK2O/ha) of RDF**,** 150% of RDF for wheat with four replications. The number of potential shoots (i.e.spikes)/m, spike length (cm), number of grains per spike, grain weight/spike, thousand grain weight were significantly influenced by fertility levels; while the effect of pruning height was found to be non-significant, except for spike length. The maximum and significantly more number of spikes/m row (67.68) was recorded with 100 per cent RDF which did not differ from 150 per cent RDF for wheat. The grain, straw and biological yield was significantly influenced by fertility levels, whereas, the effect of pruning height appeared to be non-significant. Significantly higher grain (2826 kg/ha) and straw yield (5226 kg/ha) was obtained by 150 per cent RDF and minimum (1639 kg/ha), (3536 kg/ha) by 50 per cent RDF, which is significantly lower than other fertility levels. The biological yield increase followed the exact same trends of grain and straw yields.

2.3.4 Effect of pruning on the grain yield of rice varieties.

Crop yield is a complex phenomenon and depends upon several factors. Proper varietal selection has substantial effect on final crop yield. A low yielding variety results in excessive vegetative growth due to very heavy rains in the region which results in poor grain formation and the maturity coincides with the rainy period and ultimately results in reduced grain yield, while on the other hand, varietal selection of very late sown crop results in poor growth and yield due to reduced vegetative growth, lesser tillering and grain formation (Chand et al. 2016). Pruning of the tree branches is also one of the factors that regulate the grain production of the crop. Proper pruning can lead to increase in grain production as compared to the crop grown alone.

Lavishkar (2012) reported the effects of pruning on the the growth and yield of wheat varieties under *Dalbergia sissoo* based agrisilviculture system. The main objective of the study was to find out the the most appropriate pruning intensity and its influence on quantity of timber/fuel wood ie. the most suitable and productive variety of wheat under normal sowing conditions and economics under agrisilviculture system. The tree was subjected to five pruning treatments (0, 25, 50 and 75%) and grown alongwith three wheat varieties (MP-3288, MP-3173 and Sujata). He reported that maximum grain and straw yield of wheat was recorded in open condition (27.2 q ha^{-1} and 53.23 q ha^{-1}). Variety MP3173 gave significantly higher grain yield as compared to MP3288 and Sujata. Managed agroforestry system i.e. growing of crop with different pruning intensities i.e. wheat and *D.sissoo* in 25% pruning were more profitable as compared to other pruning intensities, tree alone and crop alone.

Thakur (2013b) conducted a study on *D.sissoo*-rice based agroforestry at JNKVV, Jabalpur (India). The *D.sissoo* trees were subjected to different levels of pruning (0%, 25%, 50% and 75% intensity) and three wheat varieties (IR-36, MR-219 and WGL-32100) were grown with *D.sissoo*, including in an open condition as well. Among pruning intensities, maximum grain yield was recorded under 75% pruning (27.10 q ha^{-1}) followed by 50% pruning (21.70 q ha^{-1}) and 25% pruning (17.70 q ha^{-1}). No pruning recorded the lowest grain yield (14.10 q ha^{-1}). Variety MR-219 gave significantly higher grain yield (26.33q ha^{-1}) followed by variety IR-36 (22.13 q ha^{-1}), which in turn was significantly superior to WGL-32100 (19.30 q ha^{-1}).

Rao et al. (2016) conducted a field experiment to evaluate the growth and yield of wheat and paddy under four year old *Dalbergia sissoo* based agrisilviculture system on sodic soil in Eastern Uttar Pradesh. The experiment was laid out with treatment consisting of three varieties of wheat (NW-1067, NW-1014 and HD-2643) and paddy (Sarjoo-52, Narendra Usar-2 and Narendra Usar-3) grown in factorial randomized block design. The study reveals that the grain yield (2.32 t ha^{-1} and 2.33 t ha^{-1}) and straw yield (1.15 t ha^{-1} and 1.59 t ha^{-1}) in the varieties of wheat HD-2643 and paddy Narendra Usar-2 were found better respectively. Amongst different varieties viz. NW-1067 (wheat) and Narendra Usar-2 (paddy) were found better for cultivation under *Dalbergia sissoo* based agrisilviculture system.

2.4 Economics

Data on economic evaluation of arable crops either in isolation or in association are available. But for tree based farming systems such information appear to be scanty. Agroforestry gives more income to the farmer per unit of land than pure agriculture or forestry. The incorporation of trees in agriculture will increase the overall productivity and the marginal fall in agricultural production will be compensated by the general beneficial environmental impacts. For individual farmers, the financial returns from sale of wood will compensate for the reduction in agricultural yields. In general, yield and income from crops grown under trees are reduced than their pure cropping, but these reductions will be compensated by relatively higher fuel and fodder production from trees in agrisilviculture system. One of the reasons for enhanced interest in agrisilviculture system for possible adoption by resource poor farmers of the tropics is the belief that the inclusion of desirable woody perennials, especially nitrogen fixing trees, would cause improvement in soil fertility.

Islam *et al.* (2008) in Bangladesh have studied economic analysis on coconut-lemon based multistrata agroforestry system and found that among the seven vegetable intercrops, carrot gave the highest economic return (108937 t ha^{-1}), followed by chilli (95295 t ha^{-1}) under lemon+coconut agroforestry system. All winter vegetables were found economically profitable in multi-storey system than sole crop production systems.

Koshta et al. (2011) reported that heavy pruning (i.e. 60 cm from all sides) in guava with growing of paddy crops recorded the highest monetary return of Rs. 19129 ha^{-1} and Rs.1408 ha^{-1}, followed by moderate pruning (Rs.13705 ha^{-1} and Rs 18500 ha^{-1}), light pruning (Rs.13044 ha^{-1} and Rs.17791 ha^{-1}) while no pruning recorded the lowest monetary return of Rs.13044 ha^{-1} and Rs.17971 ha^{-1} during the year 2008 and 2009 respectively under agrihorticulture system.

Madhavilata et al. (2012a) conducted a research with the objective of assessing the economic evaluation of different tree based cropping under different levels of economic status of the farmers. The study was conducted in *Faidherbia albida* cropping system, where inclusion of nitrogen fixing tree species like *Faidherbia albida* (African babul) would cause improvement in soil fertility and increase in crop productivity. The economic analysis revealed that maize crop grown with intercropped soybean under *Faidherbia albida* trees fetched maximum monetary returns as compared to other cropping systems. The increase in gross monetary returns from maize and soybean cropping system in *Faidherbia albida* trees was by 9.5 percent and 11.8 percent over maize alone, by 0.7 percent and 13.8 percent over fieldbean, by 12.9 percent and 27.6 percent over cowpea. Similar trend was followed in the case of cost-benefit ratio (B:C) where maize and soybean cropping system in *Faidherbia albida* trees showed highest B:C ratio. The higher monetary returns obtained in maize and soybean under *Faidherbia albida* trees could be attributed to improved performance of soybean when grown as intercrop in maize in association with *Faidherbia albida* trees, indicating its compatibility in tree crop integration system. The yield of the crops were improved and returns from the crops were improved to the maximum extent when grown in association with trees because of the significant contribution by *Faidherbia albida,* which is mainly deciduous in nature, facilitating abundant light availability to the crops underneath during rainy season, and also site improvement due to addition of litter.

Madhavilata et al. (2012b) also studied the economic evaluation of crop management practices in *Hardwickia binata* based alley cropping system. The study showed that gross and monetary returns from the crop were substantially higher under sole cropping of sunflower without trees as well as intercropping of sunflower in pollarded trees, while sunflower crop when intercropped with unpollarded trees recorded negative values in monetary returns. The increase in gross and net monetary returns from the crops in sole cropping of sunflower as well as intercropping of sunflower in pollarded trees was by 56 to 58 per cent and 142 to 147 percent over intercropping of sunflower in unpollarded trees. Similarly, B:C ratio also showed the same trend of influence due to crop management practices. The improved monetary returns from the sunflower crop when grown as intercrop in pollarded trees of *Hardwickia binata* could be attributed to the least competition for resources coupled with better performance of crop growth and higher seed yields.

Chandra (2014) studied the growth and economic parameters of two intercrops *Amorphophallus paeonifolius* (Variety-Gajendra-1) and *Curcuma longa* L. (Variety- Narendra haldi-1) were intercropped in 11 year old guava (Variety- Allahabadi Safeda) orchard. The survival percentages, plant height, number of leaves, collar diameter, leaf length and rhizome length were enhanced significantly through intercropping under *P. guajava*. Under intercropping, *C. longa* yielded 150.48 q ha^{-1} and *A. paeoniifolius* gave 304.53q ha^{-1}, which was 11.57 percent and 17.54 percent higher respectively than pure crop. There was 30.25 percent improvement in the emergence of new shoots and 27.45 percent increase in fruit numbers due to intercropping. Gross profit was found to be 3.76 lakh ha^{-1} for *C. longa* and Rs. 5.48 lakh ha^{-1} for *A. paeoniifolius* in intercropping than in pure crops, which rendered gross profits of Rs.3.32 lakh ha^{-1} and Rs. 4.51 lakh ha^{-1} respectively.

Nayak et al. (2014) conducted a study to find out an economically viable system under *D.sissoo*-rice based agroforestry system, provided it is properly managed. Pruning of tree canopy is required to increase the economic return. The study was conducted in Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur. The sissoo trees were subjected to different levels of pruning (0, 25, 50 and 75% intensity) and three rice varieties (IR-36, MR-219 and WGL-32100) were grown with sissoo, including in open condition. Irrespective of rice varieties, higher net monetary return was recorded in sissoo 50% pruning+rice crop (Rs. 40311 ha^{-1}) followed by 75%

pruning (Rs.40186 ha^{-1}), 25% pruning (Rs. 36517 ha^{-1}) and lowest in no pruning + paddy (Rs.25859 ha^{-1}). Irrespective of pruning intensity, MR-219 recorded significantly higher monetary return (Rs. 38715 ha^{-1}) closely followed by IR-36 (Rs. 38363 ha^{-1}). WGL-32100 recorded the lowest net monetary return (Rs.30675 ha^{-1}).

MATERIALS AND METHODS

An experiment was carried out during *kharif* season of 2016 to study the role of pruning management on production potential of rice in *Dalbergia sissoo* Roxb. under agri-silviculture system. The details of material used, experimental procedure followed and techniques adopted during the course of investigation in the field are briefly described in this chapter.

3.1 Experimental site

The field experiment was conducted at Dusty Acre Research Farm, Department of Forestry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh. The present investigation was carried out during *kharif* season of 2016.

3.2 Climate and weather conditions

Jabalpur is situated at 23°9' North latitude and 79°58' East longitudes with an altitude of 411.78 meters above the mean sea level. The climate of the locality is characterized as typically semi-humid and tropical, which is featured by hot dry summer and cool dry winter. It is classified as “Kymore Plateau and Satpura Hills” agro-climatic zone, as per norm of National Agricultural Research Project and is broadly known as rice-wheat crop zone of Madhya Pradesh. As per recent classification of National Bureau of Soil Survey and Land use planning (NBSSLUP),

Nagpur, this area belongs to agro-ecological region number 10, named as Central High Lands (Malwa and Bundelkhand), sub-region number 10.1, named as hot sub-humid (dry) eco-region (Malwa Plateau, Vindhyan Scarpland and Narmada Valley).

Temperature extremes vary between minimum temperatures of 2.4°C in December-January month to maximum temperature of 46°C in May–June months. Based on 20 years mean meteorological data, the average annual rainfall of the locality is 1350 mm, which was mostly received between mid-June to end of September with an occasional winter showers during

December and January months. The mean monthly minimum temperature varies between 5.3 to 6.1 in December and January, and maximum temperature varies between 40 to 42°C during May and June, respectively. January is the coldest month of the year with minimum temperature being 5°C. Generally relative humidity remains very low during summer (20 to 23%); moderate (60 to 75%) during winter and it attains high value (80 to 95%) during rainy season.

3.3 Weather conditions during cropping season

Seasonal variations prevailing during the crop growth period play an important role in the growth and development of the crop which ultimately influence the final yield of crop. The weekly meteorological data during the course of investigation recorded during crop season at Meteorological Observatory, College of Agricultural Engineering, JNKVV, Jabalpur are presented in Table 3.1.

It is evident from the data that weather conditions were almost favourable for the growth and development of rice. The monsoon commenced in the third week of June and terminated in the last week of September. During the growing season of the rice (June to November 2016), the maximum temperature (41.9°C) was recorded in June and minimum temperature (28.3°C) in November. The total rainfall received during the six months was 1643 mm with 61 rainy days. Relative humidity ranged between 55 to 94% in morning and 24 to 91% in evening. The wind velocity varied between 2 to 8.7 km per hour and mean sunshine hour ranged between 1.3 to 9.3 hours per day during the growing season.

3.4 Soil

In order to find out the physico-chemical properties of soil of the experimental field, soil samples were taken randomly from different spots at a depth of 0 to 30 cm with the help of screw auger before sowing of the experiment. The soil samples were well mixed together for making representative samples. The composite samples were analyzed for physico-chemical properties of the soil in the laboratory, Department of Soil Science and Agricultural Chemistry as per standard methods. The analytical values of soil were presented in table 3.2.

Table 3.1. Weekly meteorological parameters during the cropping season (June to November 2016)

MONTH	METEO. WEEK	TEMPERATURE °C		REL.HUMIDITY (%)		WIND VELO. (KM/H)	SUN SHINE (HRS)	RAIN FALL (MM)	NO. OF RAINY DAYS
		MAX.	MIN.	MOR.	EVE.				
JUNE	22	39.8	24.6	62	27	6.3	8.9	15.2	01
	23	41.9	26.7	55	24	7.3	9	7.8	01
	24	40.1	27.6	55	32	8.7	8.1	2.4	00
	25	36.9	25.3	78	50	5.8	5.7	48.2	04
JULY	26	35.8	24.9	87	55	5.4	6.6	60.6	03
	27	29.5	23.1	94	81	8.6	2.6	373.3	07
	28	31.1	24.5	93	79	6.4	3.0	83.6	05
	29	30.4	24	91	69	7.5	3.9	63.6	03
	30	31.7	24	91	67	4.5	4.7	61.8	03
AUGUST	31	31	23.3	91	77	5	2.9	196.4	05
	32	28.6	23.6	93	82	6.8	1.3	132.8	04
	33	27	23	93	91	7	0	182.9	07
	34	28.8	22.1	90	76	5.9	6.1	263.2	6
SEPT.	35	32.2	23.7	90	70	4.3	6.1	35.2	04
	36	30.6	23	87	63	6.9	4.5	17.6	02
	37	31.7	23.6	89	65	4.5	1.9	18	01
	38	33	23.9	92	64	3.5	6.7	3.8	00
	39	29.9	23.5	94	83	4	4.6	52.4	03
OCT.	40	31.9	23.9	93	64	3	7.3	24.2	02
	41	31.5	21.3	88	51	4.2	8.0	00	00
	42	31.5	15.4	91	32	2.5	9.3	00	00
	43	31.7	15.6	82	29	2.9	8.8	00	00
NOV.	44	29.7	12.3	87	34	2.4	8.7	00	00
	45	29.7	10.6	91	24	2.2	8.1	00	00
	46	28.3	8.1	88	24	2.0	8.1	00	00
							TOTAL	1643	61

Table 3.2. Physico-chemical properties of the soil of the experimental field

Sl. No.	Particulars	Analytical values	Category	Methodology
A. Mechanical composition				
1.	Sand %	24.02	Clay Sandy loam	International pipette method (Piper, 1966)
2.	Silt %	19.83		
3.	Clay %	56.15		
B. Chemical composition				
1.	Organic carbon %	0.81	High	Walkey and Black method (Walkley and Black,1934)
2.	Available N (Kg/ha)	288.1	Medium	Alkaline Permanganate method (Jackson, 1966)
3.	Available P (Kg/ha)	20.38	High	Olsen method (Olsen et al.,1954)
4.	Available K (Kg/ha)	145	Very low	Flame photometer method (Jackson, 1973)
5.	Soil pH	5.93	Acidic	pH meter (Piper, 1967)
6.	Electrical conductivity (ds/m^2 at 25°C)	0.26	Normal	Conductivity metre sol. method (Black,1965)

3.5 Cropping history of the experimental field

Table 3.3. The following crops were grown during the past eleven years

Year	Crop (*Kharif*)	Crop (*Rabi*)
2005-06	Fallow	Wheat
2006-07	Fallow	Wheat
2007-08	Fallow	Wheat
2008-09	Fallow	Wheat
2009-10	Rice	Wheat
2010-2011	Rice	Wheat
2011-2012	Rice	Wheat
2012-2013	Rice	Wheat
2013-2014	Rice	Wheat
2014-2015	Rice	Wheat
2015-2016	Rice	Wheat

Experimental details

A. Main treatment 5 (4 pruning intensities + 1 open)

P_0 : No pruning

P_{25} : 25% pruning

P_{50} : 50% pruning

P_{75} : 75% pruning

Open : Crop only

B. Sub treatment Different duration of rice varieties

V1 : Danteshwari (early duration: 90-95 days).

V2 : MTU-1010 (medium duration: 100-110 days).

V3 : Kranti (late duration: 120-135 days).

Design	: Strip plot design
Replications	: 5
Gross plot size	: 5m × 5m
Net plot size	: 4.2m × 4.2m
Total no. of plot	: 95
Seed rate	: 100 kg/ha
Fertilizer application	: 100:60:40::N:P:K kg/ha
Row to row spacing of rice	: 20 cm
Tree spacing	: 5m ×5m
Year of plantation of *D.sissoo*	: 1998

Observations

A. On rice

(1) Pre-harvest

(i) Germination percentage (15 DAS)

(ii) Plant height (cm.) at 30 days interval

(iii) Number of tillers/MRL (at 30 days interval)

(2) At and post -harvest

1. Plant height (cm)
2. Number of tillers/MRL
3. Number of effective tillers/MRL
4. Length of panicle (cm)
5. Number of grains/panicle
6. Number of filled grains/panicle
7. Number of unfilled grains/panicle
8. 1000 grain weight (g)
9. Grain yield (q ha^{-1})
10. Straw yield (q ha^{-1})
11. Harvest index (%)

B. On *D.sissoo*

1. Height (m)
2. DBH (cm)
3. Pruned biomass (kg ha^{-1})
4. Crown spread (N-S, E-W)

5. Standing volume of the tree (m^3 ha^{-1})

6. Stand biomass (kg ha^{-1})

C. Economics of the treatments

i. Cost of cultivation of the system (Rs. ha^{-1})

ii. Gross monetary return of the system (Rs. ha^{-1})

iii. Net monetary return from the system (Rs. ha^{-1})

iv. Benefit: Cost ratio of the system (B:C ratio)

3.6 Varietal characteristics

Danteshwari:

This variety was recommended in all rice growing zones of Chhattisgarh and Madhya Pradesh. It is a derivative of Samridhi × IR 8608-298 and is recommended for direct seeded rainfed upland ecosystem of the state. Since it is an early maturity variety, it escapes most of the pests and diseases during *kharif* season and possesses good physiological tolerance to drought. It matures in 90-95 days with an average yield of 3.0 to 3.5 t ha^{-1}. The variety Danteshwari is acceptable to farmers because of its high yield potential, desirable grain type with better head rice recovery, resistant to gall midge, tolerant to brown spot and especially suitable for summer cultivation.

Kranti

This variety has been developed by the Central Rice Research Station, Raipur, India, working under Jawaharlal Nehru Agricultural University, Madhya Pradesh. It is derived from the cross C-116/IR8. Kranti is a tall plant, so it does better under rainfed conditions than other semi dwarfs. Kranti matures in 120 days when planted in *kharif* (June-October) so it fits well into double and multiple cropping patterns. Its grain is short and bold with shiny straw-coloured husk. Kranti has field resistance to bacterial blight, blast and false smut.

MTU-1010

This variety was developed by Andhra Pradesh Rice Research Institute (APRRI), Maruteru. It is a short duration variety which attains maturity in 100-110 days under normal method of cultivation. It was derived from the cross MTU 2077/IR 64. The variety is medium tall and has medium tillering habit. It is popularly grown all over A.P and also in neighbouring states. MTU-1010 is a high yielding variety with good grain quality apart from possessing submergence tolerance and performs better under flood situation. It is resistant to lodging and can withstand moderate wind velocity. This attribute of lodging resistance saves from not only loss in grain but also straw yield which is the main source of dry fodder

3.7 Cultural practices

3.7.1 Field preparation

The experimental field was thoroughly prepared by using cultivator followed by rotavator to obtain a well pulverized seed bed. The field was then levelled by using a planker.

3.7.2 Fertilizer application

The recommended dose of nitrogen, phosphorous and potash were given through Urea, SSP and MOP, respectively. The half of the nitrogen (100 kg ha^{-1}) and full quantity of phosphorous (60 kg P_2O_5 ha^{-1}) and potash (40 kg K_2O ha^{-1}) were applied at the time of sowing as basal dose.

3.7.3 Sowing

Sowing of rice was done in all the plots of experiment on 4.07.2016 (Danteshwari), 5.07.2016 (MTU-1010) and 7.07.2016 (Kranti). Required quantity of seed was first treated with Dithane M-45 @ 2-3 gm per kg of seed against seed borne diseases prior to sowing. Sowing was done in lines 20cm row to row and furrows of 5cm depth were opened with the help of pickaxe. These furrows were dressed first with fertilizer (i.e. NPK as per treatment) mixed with soil and then with seeds, covered the open furrow properly with the help of manual labour to prevent damage from bird and for proper germination.

3.7.4 Gap Filling

A week after the completion of germination the gap areas were again reseeded manually to obtain uniform plant population in all the plots.

3.7.5 Inter-culture

The weeds were removed manually from all plots at 25-30 days after sowing.

3.8 Plant protection measures

There was little incidence of insect, pest and diseases during the crop season. Therefore, plant protection measures were adopted as and when required.

3.9 Water Management

Due to less of rainfall at the end of monsoon season, irrigation was given once to rice as lifesaving irrigation on 22.9.2016.

Harvesting

Harvesting of crops was done manually with the help of sickle on 7.10.2016 (Danteshwari), 18.10.2016 (MTU-1010) and 9.11.2016 (Kranti) when they attained maturity. One row (20 cm) from either side of each plots and at same distance from both the ends (N-S, E-W directions) were harvested separately to remove the border effect. The net plots were harvested separately and the produce was left in the field for sun drying. After 2-3 days of drying, the bundles were made out of the harvested produce and tagged.

3.10 Threshing and Winnowing

After sun drying the produce was tied separately according to different varieties of rice in bundles and weighed plot wise. Threshing was done on the threshing floor by manual labourers with the help of wooden sticks. The material threshed from each plot was kept separately. Grains were separated from the straw by winnowing with the help of hand pan (Supa). After this, clean grains were weighed plot wise. The straw yield was worked out by deducting the grain yield from bundle weight (plot wise) per plot.

3.12 Observations Recorded

All the pre harvest observations of plants at different stages were recorded at 30 days interval. At and post harvest observations were recorded at the time of harvesting and after the threshing of crop.

3.12.1 Pre-harvest observations

To record various observations, five places (one meter row length) in each plot were randomly selected. One meter row length was marked by putting wooden sticks in both ends. Observations were taken from marked areas.

Germination Percentage

The number of plants/MRL was counted 15 days after sowing in marked areas in each plot. Then germination percentage was worked out on the basis of number of plants that comes out / MRL.

Plant Height (cm)

The plant height was measured in centimetre from the base up to the tip of the last fully open leaf. These observations were recorded 30, 60, 90 DAS and at harvest. The mean height was calculated by dividing the summation with five.

Number of tillers/MRL (meter row length)

Total number of tillers per meter row length at 30, 60, 90 DAS and at harvest were recorded by counting from five marked row in each plot and the mean values were calculated by dividing the summation of five by five.

3.12.2 At and post-harvest observations

Number of effective tillers/MRL

The tillers which produce panicle are termed as effective tillers. Effective tillers per meter row length were counted from already marked one meter row length at maturity stage. The average was worked out.

Length of Panicle (cm)

Five panicles from each plot were selected randomly at the time of harvesting and length of each panicle was measured from the base to tip of the panicle. Thereafter, mean length of panicle was calculated and expressed in centimetre.

Number of grains/panicle

Randomly selected five panicles were crushed by hand manually then removed the straw and count the total number of grains. Finally total number of grains counted and divided by five which gave number of grains/panicle.

Number of filled grains/panicle

All the filled grains from the total number of grains were counted manually. Then, the mean numbers of grains per panicle were computed.

Number of unfilled grains /panicle

By deducting the number of filled grains per panicle from total number of grains per panicle, the number of unfilled grains per panicle was computed.

1000 grain weight (Test weight)

Grain samples were drawn from the total produce of each net plot at the time of threshing and 1000 grains were counted manually. Thereafter, the weight of these 1000 grains were recorded on an electronic balance and later mean 1000 grains weight was computed and expressed in gram.

Grain yield (Kg ha^{-1})

After winnowing and cleaning the grains from each net plot, it was weighed on a double pan balance. The grain yield per hectare was obtained by multiplying the net plot yield by the converting factor {10,000 dividing by net area (m^2) of plot}. The yield was expressed in kilograms per hectare.

Straw yield (Kg ha^{-1})

The straw yield of each plot was determined by subtracting the grain yield from the biological yield of the respective plot. The values so obtained were converted into straw yield per ha by multiplying with net plot yield by the converting factor {10,000 dividing by net area (m^2) of plot}. The yield was expressed in kilograms per hectare.

Harvest Index (%)

Harvest index is expressed as the ratio of economic yield (grain yield) to the total biological yield (grain yield + straw yield) and expressed in percentage. It was calculated as per the formula proposed by Nichiporovich (1967).

$$\textbf{Harvest Index} = \frac{\textbf{Economic yield}}{\textbf{Biological yield}} \times 100$$

Growth observation on tree

***Dalbergia Sissoo* Roxb.(Shisham)**

Dalbergia sissoo Roxb. belong to family leguminosae, commonly called as shisham. Shisham occurs naturally throughout the sub-Himalayan tract and outer Himalayan valley from the Indus to Assam. *D. sissoo* is a fast-growing nitrogen-fixing tree which can easily be propagated and will grow on any well-drained soil, even on pure sand. It is mainly grown for its durable heartwood, being among the finest general-use timbers in South Asia and is commonly used for high class furniture and marine-grade plywood. It is also valued for fodder and soil conservation, and is also planted as an ornamental. It has been widely introduced, especially in Africa and Asia. The species is also used as a shade tree for coffee, tea, cocoa, cardamom, ginger and turmeric production. Such shade-loving crops also benefit from the trees' positive contributions to soil fertility.

Dalbergia sissoo is a pioneer species that can survive on infertile, dry and stony soils and withstand seasonal flooding. The species occurs naturally on sandy and gravelly alluvial ground along the banks of rivers and stream. There is remarkable variation in growth pattern and the yield per unit area due to the wide adaptability of the tree in different ecological sites. The leaf fall begins in November-December and also depending upon the climatic conditions.

The mean temperature and humidity play an important role than rainfall in controlling leafing and flowering.

3.12.3 Growth of the tree (height, diameter at breast height and canopy spread)

The tree growth parameters were recorded to know the effect of management practices on the tree growth.

Height (m)

The height of individual tree in each block was measured from the ground level to the tip of the main stem with the help of a measuring tape. It is expressed in meter.

Diameter at Breast Height (cm)

Diameter at breast height (dbh) of individual tree of each block was measured with the help of diameter tape at 1.37 m above ground level. It is expressed in cm.

Pruned biomass (Kg ha^{-1})

Trees were pruned (cutting of branches) as per treatment. Pruned materials were weighed accurately and pruned biomass per ha was calculated by multiplying it with a factor i.e. 400 (400 plants/ha).

Standing volume of the tree (m^3 ha^{-1})

It was estimated by using the formula,

Volume = basal area × height, where, basal area = 0.00007854 × dbh^2

Stand biomass of trees (Kg ha^{-1})

Stand biomass of trees was estimated by using formula i.e.

Weight = Volume of tree x specific gravity of tree (0.77)

Canopy spread (N-S, E-W)

Canopy of the trees was measured with the help of measuring tape. First of all East-West direction was marked with a wooden stick at the last shoot tip of each direction. The distance between North-South and East-West shoot tip was measured as crown length with the help of a measuring tape.

3.13 Economics of the treatment

The economics of the treatment is very important to find out the most profitable treatment and for determining overall economic advantages of rice crop grown with *D.sissoo* in different pruning treatments and without tree as open from practical point of view to farmers. So therefore economics of different treatments were worked out in terms of cost of cultivation, gross monetary return (GMR), net monetary return (NMR) and benefit : cost ratio (B:C ratio) to ascertain the economic viability of the treatments.

3.13.1 Cost of Cultivation

The cost of cultivation for each treatment was determined on the basis of different inputs used for raising the crop under different treatments on hectare area basis.

3.13.2 Gross monetary return (GMR)

The value obtained from the produce gained under each treatment was computed on the basis of existing market price of the produce. Total values of the produce (Grain and straw from crop and pruned biomass and stand biomass of tree) were taken as gross monetary return (GMR) per hectare under different treatments.

3.13.3 Net monetary return (NMR)

Net monetary return (NMR) per hectare under each treatment was determined by subtracting the cost of cultivation of a particular treatment from the GMR of the same treatment.

3.13.4 Benefit: Cost ratio (B:C ratio)

To estimate the benefit obtained from different treatment for each rupee of expenditure incurred, B: C ratio of each treatment was calculated as below;

$$\text{B : C ratio} = \frac{\text{Profit (Rs ha}^{-1})}{\text{Cost of cultivation (Rs ha}^{-1})}$$

3.14 Statistical Analysis

The data calculated from the experiment were tabulated and analyzed statistically by method of analysis of variance as suggested by Cochran and Cox (1950).

The significance of the treatment mean square at 5 percent level was tested with 'F' test. When 'F' test showed the significance of treatment using the significance of critical differences at 5 per cent level further tested the differences between the treatment means.

Table 3.4: **Skeleton for analysis of variance (ANOVA)**

Source of variance	d.f.	SS	MSS	'F' Value	
				Calculated value	Tabulated Value
					5%
Replication	4				3.01
Main treatment-5 pruning	4				3.01
Error (a)	16				
Sub treatment-3 Rice varities	2				4.6
Error (b)	8				
Interaction (MTxST)	8				2.24
Error (c)	32				
Total	**74**				

$$\text{Mean sum of square (MSS)} = \frac{\text{Sum of squares}}{\text{Degree of freedom}} = \frac{SS}{df}$$

$$\text{'F' value} = \frac{\text{Treatment mean sum of squares (TMSS)}}{\text{Error mean sum of squares (EMSS)}}$$

SEm± for main treatment (Pruning) = $\mathbf{\frac{E\ (a)}{R \times ST}}$

CD = SEm± × $\sqrt{2}$ x $t_{5\%}$ for error (a) at 16 df

SEm± for sub treatment (rice varieties) = $\sqrt{\frac{E\ (b)}{RT}}$

CD = SEm± x $\sqrt{2}$ x $t_{5\%}$ for error (b) at 8 df

Interaction:

SEm± for comparison of two main treatments (pruning) at same level of sub treatment (rice varieties)

$$SEm\pm = \sqrt{\frac{2\ [E\ (a) + (b-1)\ E(c)}{r \times b}}$$

CD = SEm± x $\sqrt{2}$ x $t_{5\%}$ for error df of E(c)

SEm± for comparison of two rice varieties (v) at same level of main treatment of pruning (T):

$$SEm\pm = \sqrt{\frac{2\ [E\ (b) + (a-1)\ E(c)]}{r \times a}}$$

CD = SEm± x $\sqrt{2}$ x t_5% for error df E (c) at 32 df

Where,

r	=	Number of replication
T	=	Number of main treatments (Pruning)
V	=	Number of sub treatment (rice varieties)
E (a)	=	Error variance for main plot
E (b)	=	Error variance for subplot
E (c)	=	Error variance for interaction

RESULTS

This chapter deals with the findings of the experiment regarding yield and various characters of rice and *Dalbergia sissoo* Roxb. The data recorded on various observations during the course of investigation were properly tabulated and analyzed to find out the effect of different treatments for the year of 2016-17.

4.1 Pre-harvest studies

4.1.1 Growth parameters

Germination percentage

The germination percentage was observed from the number of seeds germinated/MRL after 15 days of sowing. It is one of the main factors contributing to the yield of the crop. The mean germination percentage/MRL under different treatment is given under Table 4.1.

Table 4.1: Effect of different pruning intensities of *Dalbergia sissoo* on germination percentage of different varieties of rice in agri-silviculture system

Treatment	Germination percentage
Pruning Intensities	
P_0 - No pruning	80.7
P_1 - 25% pruning	81.5
P_2 - 50% pruning	82.0
P_3 - 75% pruning	82.5
Open- (crop alone)	82.8
SEm±	**0.74**
CD (P = 0.05)	**NS**
Rice varieties	
V1- Danteshwari (early duration)	81.6
V2- MTU-1010 (medium duration)	82.3
V3- Kranti (late duration)	81.8
SEm±	**0.61**
CD (P=0.05)	**NS**

From the above table, it is clear that the different treatments i.e. the pruning treatments in *D.sissoo* and rice varieties did not exhibit any significant effect on germination percentage per meter row length.

Plant height

Plant height has been regarded as an important regulator of heading date and yield potential in rice. The data was recorded at 30, 60, 90 days after sowing and at harvest. The data observed are tabulated in Table 4.2

Table 4.2: Effect of pruning intensities of *D. sissoo* and rice varieties on plant height (cm) at 30, 60, 90 Days after sowing and at harvest in agri-silviculture system

Treatment	Plant height (cm) at different days after sowing			
	30	**60**	**90**	**AT HARVEST**
Pruning Intensities				
P_0 - No pruning	10.9	19.4	40	49
P_1 - 25% pruning	11.8	20.9	41.9	51.6
P_2 - 50% pruning	12.0	21.5	43.4	52.8
P_3 - 75% pruning	12.1	21.9	46.1	56.4
Open -No tree	12.5	23.5	47.4	56.6
SEm±	**0.32**	**0.42**	**0.61**	**0.76**
CD (P = 0.05)	**0.95**	**1.27**	**1.82**	**2.28**
Rice Varieties				
V_1-Danteshwari (early duration)	10.5	20.4	38.1	48
V_2-MTU-1010 (medium duration)	13.2	22.4	48.2	59.3
V_3-Kranti (late duration)	11.8	21.6	44.8	52.5
SEm±	**0.20**	**0.27**	**0.37**	**1.92**
CD (P = 0.05)	**0.65**	**0.89**	**1.21**	**6.24**

In the above table 4.2, it is shown that the effect of pruning intensities in *D.sissoo* on plant height of rice is found to be significant at all stages of observations i.e. at 30, 60, 90 DAS and at harvest. Significantly highest plant height was recorded in an open condition (47.4 and 56.6 cm) at 90 DAS and at harvest which was at par with 75% pruning (46.1 and 56.4 cm). The lowest plant height was recorded at no pruning treatment (10.9, 19.4, 40 and 49 cm) followed by 25% pruning. Among the pruning treatments, 75% pruning recorded the highest plant height (12.1, 21.9, 46.1 and 56.4 cm) closely followed by 50% pruning. This is found in all the observations recorded at 30, 60, 90 DAS and at harvest.

Different rice varieties showed significant effect on plant height at all the observations (30, 60, 90 DAS and at harvest). Variety MTU-1010 recorded the highest plant height at 90 DAS and at harvest (48.2 and 59.3 cm) which is followed by variety Kranti (44.8 and 52.5 cm) respectively. Variety Danteshwari recorded the lowest plant height at all the observations (10.5, 20.4, 38.1 and 48 cm).

Number of tillers/meter row length

Different pruning intensities showed significant effect on the number of plant tillers per meter row length. The number of tillers per plant will vary according to nutrient status, variety and planting rate. Table 4.3 shows the effect of pruning intensities on the number of tillers per meter row length.

From the table 4.3, it is found that the number of tillers per meter row length increased up to 60 DAS and thereafter decreased up to maturity. Among all the treatments, open condition recorded highest number of tillers per meter row length at 30, 60 and 90 DAS (65.1, 76.5 and 70.8cm) respectively. Among the pruning treatments, 75% pruning recorded the highest number of tillers (60.3, 71.8 and 66.3 cm) which were at par with 50% pruning (58.8, 70.9 and 65.5 cm) which was followed by 25% pruning. No pruning recorded the lowest number of tillers at 30 (51.3), 60 (63.9) and 90 (57.6) days after sowing.

Effect of rice varieties on the number of tillers per meter row length was found to be significant at all the observations. Among the varieties, MTU-1010 recorded the highest number of tillers per meter row length at 60 DAS (72.6 cm) which was at par with Kranti. Danteshwari showed significantly lowest number of tillers per meter row length at 30 (55.4), 60 (68.9) and 90 (59.4) days after sowing.

Table 4.3: Effect of pruning intensities of *D. sissoo* and rice varieties on number of tillers/meter row length at 30, 60, 90 Days after sowing in agri-silviculture system

Treatment	Number of tillers/meter row length		
	30 DAS	**60 DAS**	**90DAS**
Pruning Intensities			
P_0 - No pruning	51.3	63.9	57.6
P_1 - 25% pruning	57.6	69.8	63.9
P_2 - 50% pruning	58.8	70.9	65.5
P_3 - 75% pruning	60.3	71.8	66.3
Open- No tree	65.1	76.5	70.8
SEm±	**0.36**	**0.39**	**0.43**
CD (P = 0.05)	**1.08**	**1.15**	**1.27**
Rice Varieties			
V_1-Danteshwari (early duration)	55.4	68.9	59.4
V_2-MTU-1010 (medium duration)	61.2	72.6	69.9
V_3-Kranti (late duration)	59.2	70.3	65.2
SEm±	**0.29**	**0.40**	**0.47**
CD (P = 0.05)	**0.94**	**1.29**	**1.54**

4.2 At and post harvest observations

4.2.1 Yield attributing characters

At post harvest stage, observations were recorded on the number of effective tillers/MRL, length of panicle(cm), number of grains per panicle, number of filled grains per panicle, number of unfilled grains per panicle and 1000 grain weight (g) which is shown in Table 4.4.

Table 4.4: Yield attributing characters of rice as affected bydifferent pruning intensities and rice varieties under agri-silviculture system

Treatment	No. of effective tillers/MRL	Length of panicle (cm)	No. of grains/ panicle	No. of filled grains/ panicle	No. of unfilled grains/ panicle	1000 grain weight (g)
Pruning intensities						
P_0 - No pruning	51.1	21.9	71.8	58.7	13.1	23.2
P_1 - 25% pruning	57	22.4	73.9	59.9	14	23.6
P_2 - 50% pruning	57.9	22.9	75.2	60.6	14.6	24.8
P_3 - 75% pruning	58.9	23.4	76.3	61.1	15.2	25.3
Open -No tree	64.4	24.3	77.8	61.7	16	26
SEm±	**0.35**	**0.18**	**0.30**	**0.20**	**0.20**	**0.21**
CD (P = 0.05)	**1.05**	**0.55**	**0.90**	**0.59**	**0.59**	**0.63**
Rice Varieties						
V_1-Danteshwari (early duration)	55	21.8	56.6	44.1	12.4	22.3
V_2-MTU-1010 (medium duration)	59.8	40	88.8	72.8	15.9	26.6
V_3-Kranti (late duration)	58.8	38.6	79.6	64.3	15.3	24.8
SEm±	**0.25**	**0.15**	**0.37**	**0.33**	**0.17**	**0.19**
CD (P = 0.05)	**0.82**	**0.50**	**1.21**	**1.07**	**0.55**	**0.61**

Number of effective tillers

Effects of different pruning intensities on the number of effective tillers were found significant at harvest. Open condition (no tree) recorded significantly higher number of effective tillers (64.4cm) followed by 75%

pruning. 75% pruning recorded significantly higher number of effective tillers (58.9) which was at par with 50% (57.9) but significantly superior to 25% pruning (57) and no pruning. No pruning recorded significantly lowest number of effective tillers per meter row length (51.1).

Different rice varieties showed significant effect on the number of effective tillers. MTU-1010 recorded significantly highest number of effective tillers per meter row length (59.8) which was at par with Kranti (58.8). Danteshwari variety recorded significantly lowest number of effective tillers (55).

Length of panicle (cm)

Different pruning treatments showed significant effect on the length of the panicle. Open condition recorded significantly longer panicle length (24.3cm) which was superior to other pruning treatments and no pruning. Among different pruning treatments, 75% pruning recorded longer panicles (23.4cm) closely followed by 50% pruning (22.9cm) but significantly superior to 25% (22.4cm) and no pruning (21.9cm). No pruning recorded significantly shorter panicle length.

Different rice varieties recorded significant effect on the length of panicle. Rice variety MTU-1010 recorded significantly longer length of panicle (40 cm) which was significantly superior to Kranti variety (38.6cm) and Danteshwari. Danteshwari variety recorded significantly lowest length of panicle (21.8 cm).

Number of grains per panicle

Number of grains per panicle was significantly influenced by the different pruning intensities. Open condition recorded significantly higher number of grains per panicle (77.8) which was at par with 75% pruning (76.3). Among different pruning intensities, 75% pruning recorded significantly higher number of grains per panicle (76.3) which was at par with 50% pruning (75.2) but significantly superior to 25% pruning (73.9) and no pruning. No pruning recorded significantly lowest number of grains per panicle (71.8).

Different rice varieties showed significant effect on the number of grains per panicle. Rice variety MTU-1010 recorded significantly highest number of grains per panicle (88.8) and was significantly superior to Kranti (79.6). Significantly lowest number of grains was found in Danteshwari variety (56.6).

Number of filled grains/panicle

Different pruning intensities showed significant effect on the number of filled grains per panicle. Significantly more number of filled grains was recorded in open condition (61.7) as compared to other pruning treatments and no pruning. Among the four pruning treatments, 75% (61.1) obtained significantly highest number of filled grains/panicle which was at par with 50% (60.6) but superior to 25% (59.9) and no pruning which recorded significantly lowest number of filled grains/panicle (58.7).

Different rice varieties showed significant effect on the number of filled grains/ panicle. Variety MTU-1010 recorded significantly more number of filled grains per panicle (72.8) which was superior to Kranti variety (64.3) and Danteshwari. Lowest number of filled grains per panicle was recorded in Danteshwari variety (44.1).

Number of unfilled grains per panicle

Number of unfilled grains was significantly influenced by the different pruning intensities. Open condition recorded significantly highest number of filled grains per panicle (16) which was superior to other pruning treatments and no pruning. Among different pruning treatments, 75% pruning intensity gave significantly higher number of unfilled grains/panicle (15.2) followed by 50% pruning (14.6) and 25% (14). No pruning recorded significantly lowest number of unfilled grains/panicle (13.1).

Different rice varieties showed significant effect on the number of unfilled grains per panicle. Significantly highest number of unfilled grains per panicle was recorded in MTU-1010 variety (15.9) which in turn was superior to Kranti (15.3) and Danteshwari which recorded significantly lowest number of unfilled grains per panicle (12.4).

1000 grain weight

Pruning intensities showed significant effect on the 1000 grain weight. Open condition (no tree) recorded significantly highest 1000 grain weight (26g) which was superior to the rest of the pruning treatments. Among different pruning treatments, 75% pruning gave the highest test weight (25.3g) which was at par with 50% pruning (24.8g) whereas no pruning recorded significantly lowest test weight (23.2g) at par with 25% pruning (23.6g).

1000 grain weight was significantly influenced by the different rice varieties. Significantly highest test weight was recorded by variety MTU-1010 (26.6g) which in turn was significantly superior variety Kranti (24.8g) and Danteshwari. Variety Danteshwari recorded significantly lowest 1000 grain weight (22.3g).

Grain yield and Straw yield (q ha^{-1})

From the table, Grain yield and straw yield of rice were significantly influenced by the different pruning intensities and rice varieties.

Table 4.5: Grain yield, straw yield and harvest index of rice as influenced by different pruning intensities and different rice varieties in agrisilviculture system

Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest Index (%)
Pruning intensities			
P_0 - No pruning	8.6	13.7	38.5
P_1 - 25% pruning	8.8	14.0	38.7
P_2 - 50% pruning	13.3	21.6	38.9
P_3 - 75% pruning	14.6	23.5	38.9
Open -No tree	16.0	25.9	39.0
SEm±	**1.03**	**1.70**	**0.65**
CD (P = 0.05)	**3.10**	**5.10**	**NS**
Rice Varieties			
V_1-Danteshwari (early duration)	8.9	12.9	40.9
V_2-MTU-1010 (medium duration)	14.0	25.0	37.6
V_3-Kranti (late duration)	13.9	21.3	38.2
SEm±	**0.61**	**0.97**	**1.43**
CD (P = 0.05)	**1.99**	**3.16**	**NS**

Grain yield

Different pruning intensities showed significant effect on grain yield. Open condition recorded significantly highest grain yield (16q ha^{-1}) whereas no pruning recorded significantly lowest grain yield (8.6q ha^{-1}). Among different pruning treatments, 75% pruning gave the highest grain yield (14.6q ha^{-1}) at par with 50% pruning (13.3q ha^{-1}) but significantly superior to 25% pruning (8.8 q ha^{-1}) and no pruning. No pruning gave the least grain yield (8.6 q ha^{-1}) which was at par with 25%.The percent reduction in grain yield under no pruning, 25%, 50%, and 75% as compared to open condition was 46.3%, 45%, 16.9% and 8.8% respectively. Different rice varieties showed significant effect on the grain yield of rice. Out of the three rice varieties, MTU-1010 gave significantly highest grain yield (14q ha^{-1}) at par with Kranti variety (13.9q ha^{-1}). Danteshwari variety gave significantly lowest grain yield (8.9q ha^{-1}).The percent reduction in grain yield under Kranti and Danteshwari as compared to MTU-1010 was 0.7% and 36.4% respectively.

Straw yield (q ha^{-1})

Straw yield of rice was significantly affected by the different pruning intensities. Open condition (no tree) recorded significantly highest straw yield (25.9q ha^{-1}) which was significantly superior to 50% and 25% pruning but at par with 75% pruning. Among the pruning treatments, 75% pruning gave significantly highest straw yield (23.5q ha^{-1}) which was superior to 25% pruning and no pruning but at par with 50% pruning (21.6q ha^{-1}). No pruning recorded significantly lowest straw yield (13.7q ha^{-1}) but at par with 25% pruning (14q ha^{-1}). The percent reduction in straw yield under no pruning, 25%, 50% and 75% pruning as compared to open condition was 47.1%, 45.9%, 16.6% and 9.3% respectively.

Rice varieties showed significant effect on the straw yield. Variety MTU-1010 gave significantly highest straw yield (25q ha^{-1}) followed by Kranti (21.3q ha^{-1}). Danteshwari gave significantly lowest straw yield (12.9q ha^{-1}). The percent reduction in straw yield under Kranti and Danteshwari as compared to MTU-1010 were 14.8% and 48.4% respectively. Interaction between pruning treatments and rice varieties was found to be non-significant.

Harvest index

Different pruning treatments and rice varieties showed no significant effect on harvest index.

4.2 Growth observations on tree.

Growth of Shisham (*Dalbergia* sissoo Roxb.)

Growth performance i.e. tree height, dbh, canopy spread (N-S, E-W), pruned biomass, cylindrical volume and stand biomass of shisham as influenced by different pruning intensities and rice varieties of rice under agri-silviculture system was presented in table 4.6.

Table 4.6: Morphological characters and biomass of *D. sissoo* as influenced by different pruning intensities and rice varieties under agri-silviculture system

Treatment	Height (m)	dbh (cm)	Canopy spread (m)		Pruned biomass (Kg ha^{-1})	Cylindrical Volume (m^3 ha^{-1})	Stand biomass (Kg ha^{-1})
			N-S	E-W			
Pruning Intensities							
P_0 - No pruning	11.59	26.06	7.9	7.5	----	257.98	198644.89
P_1 - 25% pruning	12.89	28.02	7.2	6.8	1644.50	329.9	254068.06
P_2 - 50% pruning	11.86	24.38	6.6	6.1	1839.40	230.51	177489.28
P_3 - 75% pruning	10.78	17.50	5.9	5.7	1979.75	99.24	76412.46
SEm±	**0.45**	**1.70**	**0.46**	**0.25**	**141.84**	**41.79**	**32175.05**
CD (P=0.05)	**1.43**	**5.43**	**1.47**	**0.80**	**NS**	**133.65**	**102910.87**
Rice varieties							
V_1-Danteshwari (early duration)	11.63	24.34	6.6	6.7	1403.1	231.66	178375.73
V_2-MTU-1010 (medium duration)	11.70	25.0	7.2	6.8	1367.5	262.91	202437.60
V_3-Kranti (late duration)	11.68	22.73	7.2	6.6	1431.1	209.49	161310.36
Tree only	11.50	23.89	6.4	6.0	1262.1	213.62	164490.99
SEm±	**0.10**	**0.95**	**0.30**	**0.34**	**95.81**	**18.59**	**14317.17**
CD (P = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Tree height (m)

Different pruning treatments showed significant effect on the tree height. 25% pruning recorded the highest tree height (12.89 m) closely followed by 50% pruning (11.86 m), no pruning (11.59 m) but was significantly superior to 75% pruning. 75% pruning intensity recorded significantly lowest tree height (10.78m).

Rice varieties recorded no significant effect on the tree height.

Diameter at breast height (1.37 m)

Pruning treatments showed significant effect on diameter at breast height. 25% pruning showed significantly higher dbh (28.02 cm) at par with no pruning (26.06 cm) and 50% (24.38cm) pruning but superior to 25% pruning. 75% pruning gave the lowest diameter at breast height (17.50cm).

Rice varieties showed no significant effect on the diameter at breast height of the tree.

Canopy spread (N-S and E-W direction)

Different pruning intensities showed significant effect on the canopy spread in both the N-S and E-W directions. No pruning gave significantly highest canopy spread in both the N-S (7.9m) and E-W (7.5 m) which was significantly superior to 75% pruning. Among the pruning treatments, 25% pruning gave the highest canopy spread having 7.2 m on the N-S and 6.8m on the E-W directions, at par with 50% pruning. 75% pruning recorded significantly lowest canopy spread on both N-S (5.9 m) and E-W (5.7m).

Rice varieties showed no significant effect on the canopy spread of the tree.

Pruned biomass (kg ha^{-1})

Different pruning intensities showed no significant effect on the pruned biomass. However as the pruning intensity increased, the pruned biomass also increased, therefore 75% pruning recorded the highest pruned biomass (1979.75 kg ha^{-1}) followed by 50% (1839.40 kg ha^{-1}) and 25% pruning which recorded the lowest pruned biomass (1644.50 kg ha^{-1}).

Rice varieties showed no significant effect on the pruned biomass.

Cylindrical volume (m^3 ha^{-1})

Cylindrical volume of trees showed significant effect on different pruning intensities. 25% pruning gave significantly highest cylindrical volume (329.9 m^3 ha^{-1}) at par with no pruning (257.9 m^3 ha^{-1}), 50% pruning (230.51 m^3 ha^{-1}) and 75% pruning (99.25 m^3 ha^{-1}) which gave the lowest volume.

Cylindrical volume of trees grown under different rice varieties showed no significant difference among them.

Stand biomass (kg ha^{-1})

Different pruning intensities have significant effect on the stand biomass of the tree. At the age of 18 years, significantly highest stand biomass was recorded in 25% pruning (254068.06 kg ha^{-1}) which was at par with no pruning (198644.89 kg ha^{-1}) and 50% pruning (177489.28 kg ha^{-1}). 75% pruning recorded the least stand biomass (76412.46 kg ha^{-1}).

Rice varieties showed no significant effect on the stand biomass.

Table 4.7: Economics analysis of different treatments on per ha area basis

S. No.	Treatments	Cost of cultivation (Rs ha^{-1})	Gross monetary return (Rs ha^{-1})	Net monetary return (Rs ha^{-1})	Benefit: Cost ratio
1	No pruning + Danteshwari	16780	65812.8	49032.8	3.9
2	No pruning + MTU-1010	16879	64406.2	47527.2	3.8
3	No pruning + Kranti	16846	63011.8	46165.8	3.7
4	Tree alone (No crop)	5050	39663.9	34613.9	7.9
5	25% pruning + Danteshwari	18380	69605.7	51225.7	3.8
6	25% pruning + MTU-1010	18479	91441.3	72962.3	4.9
7	25% pruning + Kranti	18446	69190.6	50744.6	3.8
8	Tree alone (No crop)	6650	65937.8	59287.8	9.9
9	50% pruning + Danteshwari	19180	57602.6	38422.6	3.0
10	50% pruning + MTU-1010	19279	86159	66880	4.5
11	50% pruning + Kranti	19246	80111.5	60865.5	4.2
12	Tree alone (No crop)	7450	36028.5	28578.5	4.8
13	75% pruning + Danteshwari	19580	48565.1	28985.1	2.5
14	75% pruning + MTU-1010	19679	66095.1	46416.1	3.4
15	75% pruning + Kranti	19646	50226.4	30580.4	2.6
16	Tree alone (No crop)	7850	14680.8	6830.8	1.9
17	Open crop only – Danteshwari	11730	23189.2	11459.2	2.0
18	Open crop only- MTU-1010	11829	39023	27194	3.3
19	Open crop only- Kranti	11796	42710.4	30914.4	3.6

Sale rate of grain, straw, pruned and standing tree biomass was Rs.17/kg, Rs.3/kg, Rs.2 and Rs.4/kg respectively.

Economic analysis

In the economic analysis, gross monetary return, net monetary return and benefit : cost ratio was worked out and given in table 4.7.

Cost of cultivation

In the table 4.7, it is shown that the cost of cultivation of rice was more under the pruning treatments which varies from Rs.18380 to Rs.19679 as compared to no pruning (Rs.16780-Rs.16879 $ha^{-1}yr^{-1}$), tree alone (Rs.5050-Rs.7850 $ha^{-1}yr^{-1}$) and crop alone (Rs.11730-Rs.11829 $ha^{-1}yr^{-1}$). Similarly, the cost of cultivation of MTU-1010 is more (Rs. 11829 $ha^{-1}yr^{-1}$) as compared to Kranti (Rs. 11796 $ha^{-1}yr^{-1}$) and Danteshwari (Rs.11730 $ha^{-1}yr^{-1}$)

Gross monetary return

The gross monetary treatment was more in pruning treatment as compared to no pruning treatment. Among all the treatments, 25% pruning recorded higher gross monetary return (Rs.76746 $ha^{-1}yr^{-1}$) and decreases as the pruning intensity increases. Open condition recorded the lowest gross monetary return (Rs 34962 $ha^{-1}yr^{-1}$).

Net monetary return (Rs. $ha^{-1}year^{-1}$)

Table 4.8: Net monetary return (Rs. $ha^{-1}yr^{-1}$) of different pruning intensities in *D.sissoo* with different varieties of rice

Rice varieties / Pruning intensities	Dante s-hwari	MTU-1010	Kranti	Mean	Managed AF Mean	Tree alone (no crop)
P_0 - No pruning	49033	47527	46166	47575		34613
P_1 - 25% pruning	51226	72962	50745	58311		59287
P_2 - 50% pruning	38423	66880	60866	55389	49676	28578
P_3 - 75% pruning	28985	46416	30580	35327		6830
Open – no tree	11459	27194	30914	23189		
Mean	35825	52196	43854	43958		32328

	SEm±	C.D (P=0.05)
Pruning intensities	6437.2	19296
Rice varieties	3244.6	10579.8

From the above table, it was found that pruning intensities have significant effect on the net monetary return. Managed agroforestry system gave significantly higher net monetary return (Rs.49676 $ha^{-1}yr^{-1}$) as compared to unmanaged agroforestry system. Among the managed agroforestry treatments, rice with *D. sissoo* in 25% pruning showed highest net monetary return (Rs.58311 $ha^{-1}yr^{-1}$) which was at par with 50% (Rs.55389 $ha^{-1}yr^{-1}$), no pruning (Rs.47575 $ha^{-1}yr^{-1}$) but significantly superior to 75% pruning (Rs.35327 $ha^{-1}yr^{-1}$). Open condition i.e. crop alone recorded the lowest net monetary return (Rs.23189 $ha^{-1}yr^{-1}$) followed by tree alone (Rs.32328 $ha^{-1}yr^{-1}$).

Rice varieties showed significant effect on monetary return. Rice variety MTU-1010 gave significantly higher net monetary return (Rs.52196 $ha^{-1}yr^{-1}$) at par with Kranti (Rs.43854 $ha^{-1}yr^{-1}$) but superior to variety Danteshwari (Rs. 35825 $ha^{-1}yr^{-1}$).

B: C ratio

It refers to gross monetary return under a particular treatment with each rupee of investment. 25% pruning recorded significantly highest b:c ratio (4.2) which was at par with 50% (3.9) followed by no pruning (3.8) and 75% pruning (2.8). MTU-1010 variety recorded higher b: c ratio (4.0) followed by Kranti (3.6) and Danteshwari (3.0).

Table 4.9: B:C ratio of different pruning intensities in *D.sissoo* with different varieties of rice

Pruning intensities \ Rice varieties	Danteshwari	MTU-1010	Kranti	Mean	Managed AF Mean	Tree alone (no crop)
P_0 - No pruning	3.9	3.8	3.7	3.8		7.9
P_1 - 25% pruning	3.8	4.9	3.8	4.2		9.9
P_2 - 50% pruning	3.0	4.5	4.2	3.9	3.6	4.8
P_3 - 75% pruning	2.5	3.4	2.6	2.8		1.9
Open – no tree	2.0	3.3	3.6	3.0		
Mean	3.0	4.0	3.6	3.5		6.1

	SEm±	C.D. (P=0.05)
Pruning intensities	0.4	1.1
Pruning varieties	0.2	0.6

DISCUSSION

With the increasing population and decreasing land resources in India, the pressure on the fragile land is increasing to produce more and more, so as to feed the increasing population. For this, we require improved seeds, fertilizers, insecticides, pesticides; improved tools and implements for land preparation, intercultural operations, harvesting, threshing, winnowing and latest know how to safely store the food grains. Agrisilvicultural system is an integration of annual crops with woody perennials in a land use system that enhances productivity and ensures sustainability besides environmental benefits. This type of management of land resources was practiced by farmers, grazers and indigenous people for centuries. Not only in developing countries, but in developed countries too, this concept was well appreciated for various reasons.

The structure and function of tree species in traditional agroforestry systems greatly affect the overall productivity of the system. Generally, the overall productivity (crops + trees) in agroforestry systems is higher than that in sole cropping systems. In agroforestry, inter-row spaces are mostly utilized for the cultivation of agricultural crops. The agriculture crops perform well in the earlier stages but, during the later stages the crop suffers adversely due to above and below ground competition for the limited resources. Appropriate canopy management practices like coppicing and pruning in agroforestry however, can be helpful in reducing above and below ground competition and can enhance the growth and productivity of trees and associated crops. Canopy management practices also changes root architecture thereby mitigating the adverse effect of vegetation while retaining the beneficial effect on slope stabilization and erosion control.

Keeping the above points in view, during the present investigation, efforts were made to understand the effects of pruning of *D.sissoo* on the growth and yield of rice varieties for their successful cultivation as intercrops with and without *D.sissoo* plantation under rainfed conditions with economic appraisal of the systems. The data of practical utility generated during this study and assessed through several parameters are discussed in the following:

Agroclimatic variation

All climate elements, singly or in combination, affect crop production. The climatic elements of greatest significance to agricultural production in India are rainfall, temperature, relative humidity, light and wind velocity etc.

Weather condition

The climate is generally the first element taken into account as it is considered a stability factor, although seasonal variations and the climatic variability are also to be considered. The meteorological data (i.e. temperature, relative humidity, wind velocity, sunshine hours, rainfall and number of rainy days) for the year 2016 is given in table 1. The meteorological data was obtained from Meteorological Observatory, Agriculture College of Engineering, JNKVV, Jabalpur. The total rainfall received during the six months was 1643mm with 61 days of rain showers and the relative humidity ranged between 55 to 94% in morning and 24 to 91% in evening. There was heavy rainfall during July (582.3mm) and August (775.3mm) which had effects on the establishment and growth of plant, similarly reproduction phase i.e. flowering and seed formation stage. Due to shortage of moisture during the month of September (127mm) i.e. during tillering and flowering stage, protective irrigation, were given for proper growth.

Edaphic condition

Soil is one of the big reservoirs and sinker of the total terrestrial organic carbon through the decomposition of plant litter naturally. Organic matter plays a big role for the productivity of soil by making plant nutrients in available form, acts as a buffer to rectify the toxicity and unfavourable soil conditions, reduces soil erosion, made the soil physical properties favourable for plant growth. The physico-chemical status was given in Table no. 2. The data on physico-chemical properties showed that fertility status of the soil of the experimental area was fairly homogenous and treatment exhibited their own effects during the investigation. This shows that variation on yield under experimental plots was mainly due to the effect of treatments tested and not by the heterogeneity of soil during the investigation. The inclusion of trees in agricultural systems can also optimize nutrient cycling and have positive effects on soil chemical and physical properties. This process is especially important in tropical soils, where a high degree of weathering has created deep, leached soils that are poor in plant nutrients (Pinho et al., 2012).

Growth parameters (Plant height and number of tillers/meter row length)

Effect of pruning intensities

Plant height of rice was observed at 30, 60, 90 days after sowing and at harvest. The pruning intensities showed significant effect on the plant height at all observations (i.e. 30, 60, 90 DAS and at harvest). Open condition (crop only) recorded significantly highest plant height at all the observations (12.5cm, 23.5cm, 47.4cm and 56.6cm) as compared to crops grown under tree with different pruning intensities. Higher values of plant height were recorded in the open condition probably due to the uninterrupted solar radiation available in the open plots. Similar results were reported by Thakur and Singh (2008).

Among the pruning intensities (no pruning, 25%, 50% and 75%), 75% recorded the highest plant height (12.1cm, 23.5cm, 47.4cm and 56.6cm) at all the observations (30, 60, 90 DAS and at harvest), followed by 50% (12cm, 21.5cm, 43.4cm, 52.8cm) and 25% (11.8cm, 20.9cm, 41.9cm and 51.6cm) which were at par with each other. This is due to the fact that, 75% tree pruning had minimum canopy spread so there was minimum competition for light with crop. Similar results were also reported by Patel (2015). Among all the treatments, no pruning recorded significantly lowest plant height (10.9cm, 19.4cm, 40cm and 49cm). This is due to the fact that in no pruning maximum canopy occurred as compared to pruned tree and the tree canopy could have adverse effects on the penetration of light and due to this shading effect on the understorey annual crops, their growth is affected.

Number of tillers per meter row length was significantly influenced by the pruning intensity treatments. The observation was taken at 30, 60, 90 days after sowing. The number of tillers were more in 30 to 60 DAS but reduced during 90 DAS due to the death of some plants as a result of competition for light, space and nutrients. Open condition recorded the highest number of tillers (65.1, 76.5, and 70.5) during all the observations. No pruning, 25%, 50% and 75% pruning treatments were comparatively lower than open condition, as open condition had more sunlight penetration and minimum competition for light as well as nutrients. Islam et al. (2006) also reported that yield of rice was reduced due to adverse effect of trees as compared to outside of the tree canopy. However, among the entire pruning treatments 75% pruning gave the highest tillers per meter row length (60.3, 71.8 and 66.3) followed by 50% (58.8, 70.9 and 65.5), 25% (57.6, 69.8 and 63.9cm) and no pruning (51.3, 63.9 and 57.6). Tree without pruning having maximum canopy spread in all directions (viz., north, south, east and west) recorded the lowest number of tillers per meter row length as the tree prohibited the penetration of light to the understory crops. Bargali et al., (2010) reported that the rice productivity reduced with the increase in tree age. They further reported that 10% removal of basal tree branches, grain yield of rice increased significantly over the unmanaged (no pruning) condition.

Rice varieties

Different rice varieties had significant effect on the plant height. Rice variety MTU-1010 obtained the highest plant height (13.2cm, 22.4cm, 48.2cm and 59.3cm) at all the observations followed by Kranti (11.8cm, 21.6cm, 44.8cm and 52.5cm) and Danteshwari (10.5cm, 20.4cm, 38.1cm and 48cm) having significantly lowest height. MTU-1010 gave the highest plant tillers per meter row length at 60 DAS (70.3) which was at par with Kranti (72.6). Danteshwari recorded the lowest plant tillers in all the observations (55.4, 68.9 and 59.4).This may be attributed to the strong performance and genetic expression of the variety once favourable climate conditions and availability of more water due to excessive rainfall, which coincides with the active growth period of the crop. Rao et al., (2016) and Thakur (2013a) gave similar results.

Yield attributing characters (at harvest)

Pruning intensities

The yield attributing characters i.e. number of effective tillers per MRL, length of panicle, number of grains/panicle, number of filled grains/panicle, number of unfilled grains/panicle and 1000 grain weight was found to be significantly influenced by different pruning intensities. Compared to the pruning treatments, open condition recorded the highest number of effective tillers (64.4), length of panicle (24.3cm), number of grains per panicle (77.8), number of filled grains per panicle (61.7), number of unfilled grains per panicle (16) and 1000 grain weight (26g). This is because the crop in open condition was grown alone with no tree. So there was no competition between the tree and the crop for space, nutrients etc. Similarly since there was no tree, there will be more availability of photosynthetically active radiation, which gives maximum results in terms of yield attributing characters. Similar results were given by Singh et al., (2014), Chauhan et al., (2012) and Patel (2015). Among the pruning treatments, 75% gave higher yield attributes followed by 50%, 25% and no pruning. The yield attributes values decreases with the decreasing pruning intensities in which no pruning recorded the least. The probable reason would be that the shade resulting from managed and unmanaged *D.sissoo.* has adversely affected the rate of important physiological processes like photosynthesis. The higher shade intensities had more adverse effect on these parameters which in turn regulate the growth and of yield related parameters. Reduction in solar radiation influences the physiological processes (Kumar, 1999). With the increase in shade intensities, there was subsequent decrease in the yield related parameters (Thakur and Singh, 2008).

Rice varieties

Yield attributing characters i.e. number of effective tillers, length of panicle, number of grains/panicle, number of filled grains, number of unfilled grains and 1000 grain weight was found to be significantly influenced by the different rice varieties.

Medium duration rice variety MTU-1010 recorded highest number of effective tillers (59.8), length of panicle (40cm), number of grains/panicle (88.8), number of filled grains/panicle (72.8), number of unfilled grains/panicle (15.9) and 1000 grain weight (26.6g) as compared to Kranti and Danteshwari. This may be due to genetical characters of the rice varieties.

Grain and straw yield

Effect of pruning intensities

Open condition i.e. crop grown without tree recorded the highest grain yield (16q ha^{-1}) as compared to grain yields obtained by other pruning treatments (no pruning, 25%, 50% and 75% pruning). This could be due to the fact that in open condition maximum sunlight was available which resulted in more number of tillers per meter row length (76.5), number of effective tillers (64.4), plant height (56.6cm) and length of panicle (24.3) as compared to crops grown in other pruning treatments. Tillers are the grain bearing part of rice crops (Li et al., 2003). Newaj et al., (2001) also reported that trees grown along with crops have negative effect on the growth and yield of associated crop. He further stated that crops grown alone (without trees) gave maximum yield as compared to crops grown under agroforestry system.

Among the pruning intensity treatments, grain yield increases with the increasing pruning intensities therefore 75% recorded the highest grain yield (14.6q ha^{-1}) at par with 50% (13.3q ha^{-1}) and significantly superior to no pruning (8.6q ha^{-1}) and 25% (8.8q ha^{-1}). Since 75% pruning treatment had less canopy spread, therefore availability of light was maximum which increased the rate of photosynthesis in crop plants which in turn resulted in accumulation of more photosynthates in plants and their translocation from source to sink. Pruning is most common and also of utmost importance. Pruning facilitates penetration of light and alleviates shading of understory crop and simultaneously increases the merchantable value of the tree component. In agroforestry systems, trees and crops compete inevitably for light, nutrients and other resources. Pruning of the tree component is a powerful approach to regulate this competition (Frank and Eduardo, 2003).

Among all the treatments open condition recorded the highest straw yield (25.9q ha^{-1}) when compared with other pruning treatments. This may be due to the fact that, open condition produced taller plants and more number of tillers per meter row length; therefore, higher straw yield was obtained. Dar (2007) also reported in detail the effect of pruning in 5 and 6 years old *Albizia procera* on performance of intercrops. He tried 50 and 70 per cent canopy pruning against no pruning and observed that the growth, yield and yield attributing characters of intercrops black gram, green gram, mustard and wheat were significantly higher in 70 per cent pruning than 50 per cent canopy pruning and control (un-pruned) during two years of study. 75% pruning recorded the highest straw yield (23.5q ha^{-1}) among the pruning treatments followed by 50% (21.6q ha^{-1}), 25% (14q ha^{-1}). No pruning recorded significantly least straw yield (13.7q ha^{-1}) which is due to the fact that no pruning had more canopy spread thereby, hindering the availability of sunlight to the under storey crops.

Rice varieties

MTU-1010 gave significantly higher grain yield (14q ha^{-1}) as compared to other varieties. This is because MTU-1010 recorded higher yield attributing characters i.e. maximum number of effective tillers per meter row length (59.8), plant height (59.3cm), length of panicle (40cm) and number of grains per panicle (88.8). Canopy pruning reduces shading effect and increase the light availability to understory rice crop which increased the yield attributes of their intercrops. Similar results were given by Thakur (2013a).

Variety MTU-1010 recorded the highest straw yield (25q ha^{-1}) which was significantly superior to Kranti (21.3 q ha^{-1}) and Danteshwari (12.9 q ha^{-1}). The straw yield is the resultant of plant height and tillering behaviour of the crop.

Harvest index

Different pruning intensity and rice varieties did not show any significant effect on grain yield and biological yield. However open condition recorded more grain straw ratio than other pruning treatments.

Morphological characters of shisham

Tree height (m), dbh (cm) and canopy spread (N-S & E-W)

Pruning intensities

Pruning treatment showed significant effect on the height of the tree. The tree height decreases with the increasing pruning intensities. 25% pruning treatment recorded the highest tree height (12.89m) which is superior to no pruning (11.59m), 50% pruning (11.86m) and 75% pruning (10.78m). 75% pruning recorded the least tree height probably because the impact of pruning on tree growth and development depends not only on the amount of branches and leaves removed but also on the tree size, growth habits, pruning seasons, intensity and pruning frequency. Meena (2008) also reported that in agri-silviculture system, among different pruning intensities (no pruning, 25%, 50% and 75% pruning) of *Dalbergia sissoo*, significantly more tree height was recorded in 25% pruning (7.92 m) followed by no pruning (7.47 m) and 50% pruning (7.33 m) where 75% pruning recorded the lowest tree height. Pinkard and Beadle (1998) studied the effects of pruning on growth and stem shape of *Eucalyptus nitens*. The trees were pruned to remove 0, 50% or 70% of the lower green crown length. The 50% treatment had no impact on height or diameter increment in the two years following treatment, but removal of 70% of the lower crown length resulted in significant decreases in both height and diameter increment.

Diameter at breast height of the tree was significantly influenced by the pruning varieties. Among all the treatments, 25% pruning recorded significantly highest dbh (28.02cm) which was at par with no pruning (26.06cm) and was found to be significantly superior to 50% (24.38cm) and 75% pruning (17.50cm). Pruning is an important silvicultural technique from an economic standpoint; however it may reduce total diameter growth due to reduction in the tree leaf area. The probable reason 25% pruning acquired more dbh maybe because the trees recovered the leaf area loss and consequently growth loss by increasing their photosynthetic activity following defoliation (Alcorn et al., 2008). Savill et al., 1997, citing research conducted in *Cryptomeria japonica* by Wang et al., 1980, informed that removing 10% or slightly more of the live crown actually improved the growth. He further reported that pruning of more than 1/3 of canopy will reduce diameter growth. Similar reports were also given by Rai et al., (2008), Schulte et al., (2003) and Elfadl and Luukanen (2003).

Canopy spread in both N-S and E-W shows significant effect on the different pruning intensities. No pruning recorded the maximum canopy spread in both N-S (7.9m) and E-W (7.5) directions. The percent reduction in canopy spread in N-S direction in 25%, 50% and 75% as compared to no pruning was 8.86%, 10.57% and 25.31% respectively. Similarly, the percent reduction in canopy spread in E-S direction in 25%, 50% and 75% as compared to no pruning was 9.33%, 18.66% and 24% respectively. The reason no pruning treatment have more canopy spread is due to the fact that there was no cutting of branches whereas other pruning treatments were subjected to different intensities of pruning (25%, 50% and 75%). Less pruning done means more canopy spread. A similar result was given by Palsaniya et al. (2012) and Kumar (2016).

Rice varieties

Rice varieties grown along with *Dalbergia sissoo* showed no significant effect on the tree height, dbh and canopy spread (N-S and E-W). The probable reason would be that the fertilizer, irrigation and cultural practices applied to the crops was utilized by crop itself and negligible amount utilized by trees, hence showed no effect on growth parameters of tree. Karwar *et al*., (2006) reported that intercropping of arable crops didn’t influence visible antagonistic effect on the growth of trees.

Biomass

Pruned biomass (kg ha^{-1}), cylindrical volume (m^3 ha^{-1}) and stand biomass (kg ha^{-1})

Pruning intensities

Pruned biomass was not significantly influenced by the different pruning intensities. However, 75% pruning recorded the highest pruned biomass (1979.75 kg ha^{-1}) when compared to other pruning treatments. This is because 75% pruning had more pruned branches which directly increased the pruned biomass. Accordingly 25% and 50% pruning treatment had less pruned biomass as the pruned branches were comparatively lesser than 75% pruning.

Cylindrical volume of standing trees was significantly influenced by different pruning intensities. 25% pruning treatment recorded the highest cylindrical volume (329.9 m^3 ha^{-1}) which was significantly superior to no pruning and 50% and 75% pruning. 25% pruning recorded higher dbh (28.02cm) and tree height (12.89m) and since cylindrical volume is a product of height and dbh, therefore it resulted in higher cylindrical volume as compared to other pruning treatments. This is because when trees are pruned, leaves and branches from the lower part of the crown which changes the stem shape to a more cylindrical form and increases the clear bole length, resulting in more biomass deposition in bole than other components. Nayak et al. (2011) also revealed that 25% pruning recorded highest dbh (19.91), cylindrical volume (124.12 m^3 ha) and stand biomass (95571.7 kg ha^{-1}). Total biomass production was higher in 25% pruning and lowest in 75% pruning.

Stand biomass was significantly influenced by different pruning intensities. 25% recorded the highest stand biomass (254068.06 kg ha^{-1}) as compared to no pruning (198644.89 kg ha^{-1}), 50% (177489.28 kg ha^{-1}) and 75% pruning (76412 kg ha^{-1}). This is due to the fact that 25% pruning recorded the highest dbh and height and stand biomass is the resultant value of dbh and height. The results showed that more pruning reduces biomass production and this reduction has positive correlation with amount of pruning. And this reduction may be due to the diminished overall photosynthesis of pruned trees, because pruning of branches leads to a decrease in remaining leaf area and to a decrease in the number of buds from which new branches and leaves can be produced. Pruning leads to considerable reduction in leaf area, and this leads to an overall reduction in assimilate production of trees. Furthermore, while pruning takes away branches and leaves, the stem and root systems are retained. Thus a large proportion of assimilates produced by the residual leaf tissue after pruning (especially under intensive pruning) has to be used for the maintenance of a relatively large mass of remaining unproductive, living support tissue. As a result, assimilate investments in future photosynthetic production (via the formation of new leaf area) becomes smaller, and the regrowth of trees will be reduced consequently. A research by Zeng (2001) reported that biomass production of pruned *Ficus microcarpa*, *Ficus virens* and *Cinnamomum camphora* trees decreased following pruning, and this reduction was correlated with pruning intensity. Repeated pruning aggravated the decrease of biomass production.

Rice varieties

Growing of tree alone or along with rice varieties had no significant effect on the pruned biomass, cylindrical volume and stand biomass.

Economics

Cost of cultivation

The cost of cultivation was found more when *Dalbergia sissoo* were pruned in different pruning intensities i.e. 25%, 50% and 75% (Rs.19679 $ha^{-1}yr^{-1}$) as compared to crop grown alone (Rs.11829 $ha^{-1}yr^{-1}$) and no pruning (Rs.1687 $ha^{-1}yr^{-1}$). This would be due to the fact that pruning management incurred more expenditure under agri-silviculture system whereas no pruning incurred the lowest expenditure.

Gross monetary return

Gross monetary return was more in pruning treatment (i.e. managed agroforestry system) as compared to no pruning treatment (i.e. unmanaged agroforestry system). Among different pruning treatments, 25% pruning with

MTU-1010 recorded the highest GMR (Rs. 91441 $ha^{-1}yr^{-1}$) and decreased with increasing pruning intensities, therefore 75% pruning with Danteshwari recorded the least GMR (Rs. 48565 $ha^{-1}yr^{-1}$). Tree grown alone recorded the lowest gross monetary return (Rs. 14680 $ha^{-1}yr^{-1}$).

The reason 75% recorded the least GMR is because there was more expenditure in pruning and less return from the stand biomass. Similar results were given by Meena (2008) and Nayak (2014).

Net monetary return

Managed agroforestry system (i.e. pruning intensity treatment) showed significantly higher net monetary system as compared to unmanaged agroforestry system (i.e. no pruning). Higher net monetary return was recorded in rice with *D.sissoo* in 25% pruning (Rs. 58311 $ha^{-1}yr^{-1}$) which was at par with 50% (Rs. 55389 $ha^{-1}yr^{-1}$), no pruning (Rs.35327 $ha^{-1}yr^{-1}$) and 75% pruning (Rs. 35327 $ha^{-1}yr^{-1}$). The probable reason of higher monetary return under 25% pruning is due to higher average return from tree biomass as compared other pruning treatments. Managed agroforestry system, 25% pruning gave higher monetary return as compared to crop alone and tree alone. The probable reason of higher return in managed agroforestry system is that sufficient return is obtained from both tree and crop components, whereas in tree alone or crop alone, return is obtained only from one component either from tree or crop alone. Similar results were given by Nayak et al., (2014).

B: C ratio

It refers to gross monetary return under a particular treatment with each rupee of investment. 25% pruning recorded the highest b:c ratio (4.2) followed by 50% pruning (3.9), no pruning (3.8) and 75% pruning (2.8). 75% pruning recorded the recorded significantly lowest b:c ratio. Similar results were given by Chandra (2014), Madhavilata et al., (2012a).

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

6.1 Summary

The present study entitled, "Differential response of pruning intensities in *Dalbergia sissoo* Roxb. on growth and yield of rice varieties under agri-silviculture system" was carried out during the *kharif* season of 2016. The field experiment was conducted in the Dusty Acre research Farm, Department of Forestry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P). The main objectives of the research were to find the appropriate pruning intensity for wood and grain production, suitable variety of rice under different pruning management and overall economics of the system.

The total rainfall received during the six months was 1643mm with 61 days of rain showers. There was heavy rainfall during July (582.3mm) and August (775.3mm) which resulted in poor yield of rice (washing of pollen grains in flowering and ripening). Other weather parameters viz., temperature (minimum and maximum), relative humidity (morning and evening), sunshine hours were favourable for proper growth and development of rice. Due to shortage of moisture during the month of September (127mm) i.e. during tillering and flowering stage, protective irrigation were given for proper growth. The soil of experimental field was clayey sandy loam in texture. The soil pH is acidic (5.93) in reaction with normal electrical conductivity (0.26 ds/M^2) at 25°C. Experimental site was high in organic carbon content (10.81%), medium in available nitrogen (288.1 kg ha^{-1}), high in available phosphorous (20.38 kg ha^{-1}) and very low in available potash (145 kg ha^{-1}). The total 15 treatments viz. 5 pruning intensities (4 pruning treatments + 1 open) in main plot and 3 rice varieties in subplot as mentioned below were tested in strip plot design with 5 replications.

Treatment Details

A. Main treatment: 5 [4 intensities of pruning in *D.sissoo* + 1 open - no tree]

P_0 - No Pruning

P_{25} - 25 % pruning

P_{50} - 50 % pruning

P_{75} - 75 % Pruning

Open - No tree

B. Sub Treatment: 3 (rice varieties)

V_1 - Danteshwari (early duration).

V_2 - MTU-1010 (medium duration).

V_3 - Kranti (late duration).

Various observations on growth parameters in crop viz., germination percentage, plant height; number of tillers/meter row length and yield attributes viz., effective tillers/meter row length, panicle length, number of grains/panicle, number of filled grains/panicle, number of unfilled grains/panicle, 1000 grain weight, grain yield, straw yield and harvest index were recorded. In tree, various parameters viz., height, dbh, canopy spread in N-S and E-W direction, pruned biomass, cylindrical volume and stand biomass of trees were recorded. The economics of the treatments were also determined in terms of cost of cultivation, gross monetary return, net monetary returns per hectare area basis and benefit: cost ratio. Data pertaining to various observations were tabulated and subjected to statistical analysis. After this the result were interpreted as under.

Significant achievement

Growth parameters

Plant height and number of tillers per meter row length under different pruning treatment showed significant effect at all observations i.e. at 30, 60, 90 DAS and at harvest. Open condition (without tree) recorded the highest plant height and number of tillers per meter row length at various stages of observations. Among different pruning intensities (0, 25%, 50% and 75%), 75% pruning recorded the highest number of plant height and plant tillers per meter row length which was followed by 50% and 25% pruning treatment. No pruning treatment recorded the lowest plant height and number of plant tillers/ meter row length.

Rice varieties showed significant effect on the plant height and plant tillers per meter row length. MTU-1010 recorded the highest plant height and number of tillers per meter row length at all stages of observations (30, 60, 90 DAS and at harvest) which was significantly superior to Kranti and Danteshwari.

Yield attributing characters

Yield attributing characters viz., number of effective tillers/meter row length, length of panicle, number of filled grains / panicle and 1000 grain weight were affected significantly by different pruning treatments. Open condition (without tree) recorded the highest number of effective tillers per meter row length, length of panicle, number of filled grains and 1000 grain weight as compared to other pruning treatments. 75% pruning intensity recorded significantly highest number of effective tillers per meter row length, length of panicle, number of filled grains per panicle and 1000 grain weight which was at par with 50% pruning and was significantly superior to 25% and no pruning. No pruning recorded significantly lowest yield attributing characters.

Yield attributing characters was significantly influenced by different rice varieties. Variety MTU-1010 gave significantly higher number of effective tillers, length of panicle, number of filled grains per panicle and 1000 grain weight which was at par with Kranti but significantly superior to variety Danteshwari.

Grain and straw yield

Different pruning intensities showed significant effect on the grain and straw yield. Open condition (without tree) recorded significantly higher grain yield and straw yield as compared to other pruning treatments. Among all the pruning treatments, 75% pruning recorded the highest grain and straw yield which was at par with 50% pruning followed by 25% and no pruning. Significantly lowest grain and straw yield was recorded by no pruning intensity.

Rice varieties had significant influence on the grain and straw yield. MTU-1010 variety showed significantly highest grain and straw yield followed by Kranti and Danteshwari.

Morphological characters of Shisham

All the morphological characters (except pruned biomass) were significantly affected by pruning treatment. 25% pruning treatment recorded the higher tree height, dbh, cylindrical volume and stand biomass as compared to other pruning treatments (0, 50% and 75%). Canopy spread in both N-S and E-W directions was more in no pruning as there was no removal of branches. 75% pruning treatment recorded more pruned biomass followed by 50% and 25% pruning intensity.

Morphological characters of shisham showed no significant effect on the rice varieties

Monetary return.

Managed agroforestry system (with pruning intensity) i.e. rice with *D.sissoo* in 25% pruning gave the highest profit (Rs.58311 $ha^{-1}yr^{-1}$) as compared to 50% pruning (Rs.55389 $ha^{-1}yr^{-1}$), no pruning (Rs.47575 $ha^{-1}yr^{-1}$), tree alone (Rs.32328 $ha^{-1}yr^{-1}$) and crop alone (Rs.23189 $ha^{-1}yr^{-1}$).

6.2 Conclusion

Sissoo + Rice

Pruning intensities

- Open condition (without tree) recorded significantly maximum grain and straw yield (16q ha^{-1} and 25.9q ha^{-1}) respectively. No pruning recorded the lowest grain yield and straw yield (8.6q ha^{-1} and 13.7q ha^{-1}) respectively. The percent reduction in grain and straw yield under no pruning as compared to open condition was 46.3% and 47.1% respectively.
- Among different pruning intensities, 75% pruning recorded significantly higher grain yield (14.6q ha^{-1}) and straw yield (23.5q ha^{-1})

as compared to 50% and 25% pruning. No pruning recorded the lowest grain yield (8.6q ha^{-1}) and straw yield (13.7q ha^{-1})

- The percent reduction in grain yield under no pruning, 25%, 50% and 75% as compared to open condition was 46.3%, 45%, 16.9% and 8.8% respectively.

Rice varieties

- Variety MTU-1010 gave significantly higher grain yield (14q ha^{-1}) which was at par with Kranti (13.9q ha^{-1}) followed by Danteshwari (8.9q ha^{-1}).
- The percent reduction in grain yield under Kranti and Danteshwari as compared to MTU-1010 was 0.7% and 35.4% respectively.

Tree parameters

Among all the pruning treatments (no pruning, 25% 50% and 75%), 25% recorded significantly tree height (12.89m), dbh (28.02cm), cylindrical volume (329.9m^3ha^{-1}) and stand biomass (254068.06 kg ha^{-1}).

Economics

Rice with *D.sissoo* in 25% pruning gave the highest profit (Rs.58311 $ha^{-1}yr^{-1}$) as compared to 50% (Rs.55389 ha^{-1} yr^{-1}), no pruning (Rs. 47575 $ha^{-1}yr^{-1}$), tree alone (Rs.32328 $ha^{-1}yr^{-1}$) and crop alone (Rs.23189 $ha^{-1}yr^{-1}$).

6.3 Suggestions

1. Since the present findings are drawn on the basis of the results of only one year experiment, the study should be repeated for 2 to 3 years to confirm the findings.
2. Varieties that are newly introduced with D.sissoo are highly yielded and most suitable for rainfed and partial irrigated. These rice varieties should be tested in different agroclimatic zones. Varieties should be tested with different level of seed rates and fertilizer dose for higher return.
3. Since shisham and babul are the major timber and fodder tree species of the state, experiments should be conducted with different crops along with the aforementioned trees with different pruning intensities.

4. Experiments should be conducted in different shading condition with different pruning management with different crops.
5. Some common *kharif* and *rabi* crops grown by poor and marginal farmers under unirrigated and partial irrigated condition should be tested with their trees to find out the most suitable and profitable tree crop interaction and agri-silviculture system.
6. Multipurpose tree species should be introduced as it will be beneficial for the farmers.
7. The selection of intercropping components must be based on the principle of minimizing the competition and maximizing complimentarily among themselves.
8. Adequate care and proper management are essential for maximum productivity in the intercropping systems.
9- Major fruit trees of the state (mango, guava etc.) should be introduced.

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Appendix-1

Mean sum of square for different growth and yield attributing characters and yields of paddy

Sources of Variance	df	Mean Sum of Square									
		Germin ation %	Plant height (cm)				No. of tillers/MRL			Effective tillers/MRL	Length of panicle (cm)
			30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS		
Replication	4	57.1	2.3	4.7	17.9	3.2	1.1	4.0	6.3	6.1	0.4
Pruning (P)	4	10.3	5.1	34.0	137.8	156.6	377.8	307.3	344.0	338.4	13.0
Error (a)	16	8.3	1.5	2.7	5.6	8.7	2.0	2.2	2.7	1.8	0.5
Paddy varieties	2	3.8	45.6	24.9	661.0	796.6	216.1	88.0	693.5	162.6	29.6
Error (b)	8	7.5	0.8	1.5	2.7	73.4	1.7	3.1	4.5	1.3	0.5
Interaction (P×V)	8	0.7	1.2	4.5	19.2	98.6	2.7	1.7	0.9	0.1	0.5
Error (c)	32	6.6	0.7	2.7	2.2	11.4	2.6	3.4	5.3	1.1	0.4

Sources of Variance	df	Mean Sum of Square					
		No. of filled grains/panicle	No. of unfilled grains/panicle	1000 Grain wt. (gm)	Grain Yield (q ha^{-1})	Straw Yield (q ha^{-1})	Harvest Index (%)
Replication	4	0.8	0.3	0.7	33.4	72.8	6.8
Pruning (P)	4	20.9	19.3	19.7	173.9	469.2	0.4
Error (a)	16	0.6	0.6	0.7	16.1	43.4	6.3
Paddy varieties	2.0	5441.1	86.7	117.4	212.8	961.3	78.5
Error (b)	8.0	2.1	0.6	0.7	7.5	18.8	41.0
Interaction (PxV)	8.0	0.9	0.4	1.2	22.8	67.1	170.5
Error (c)	32.0	1.4	0.6	0.5	3.9	12.3	31.8

Appendix-2

Mean sum of square for different morphological characters and biomass of Shisham

Sources of Variance	df	MSS						
		Height (m)	Dbh (cm)	Cylindrical vol. ($m^3 ha^{-1}$)	Stand biomass (kg ha^{-1})	Canopy spread (m)		Pruned biomass (kg ha^{-1})
						N-S	E-W	
Replication	4	1.6	27.57	956.55	1791780114	4.65	2.91	86613
Pruning (P)	3	12.11	195.38	43286.25	27279042301	38.54	35.49	4517378
Error (a)	12	4.26	34.78	4433.38	3689041962	2.09	1.49	82287
Paddy varieties	3	0.26	0.92	1860.86	1876911273	2.90	2.45	20022
Error (b)	12	0.62	7.38	1967.37	1327126036	0.58	2.54	46235
Interaction (PxST)	9	0.87	4.03	426.29	453980058	1.55	1.32	18365
Error (c)	36	6.58	71.12	15691	9999706750	11.50	11.89	876331

Appendix-3

(A) Estimation of cost of cultivation:

S. No.	Particular	Input (per ha)	Rate (Rs)	Cost (Rs ha^{-1})
1.	**Land preparation**			
(a)	Harrowing by cultivator	One pass	650	650
(b)	Disk harrow	Two pass	450	900
(c)	Planker	One pass	350	350
2.	**Seed and sowing**			
(a)	Cost of seed - Danteshwari variety - MTU-1010 variety - Kranti variety	 33 kg 33 kg 33 kg	 Rs.20/kg Rs.23/kg Rs.22/kg	 660 759 726
(b)	Seed treatment	200gm	2.5 g/kg	170
(c)	Seed sowing	7 man days	200	1400
3.	**Fertilizer**			
(a)	Cost of fertilizer	96 kg Urea	Rs 5/Kg N	480
		374 kg SSP	Rs 4/Kg P_2O_5	1496
		68 kg MOP	Rs 10/Kg K_2O	680
(b)	Application charges	2 man days	200	400
4.	**Irrigation (Including application charges)**	One	500	500
5.	**Plant Protection**	-	-	544
6.	**Weed control by weedicide**	-	-	1500
7.	**Harvesting,Threshing by combiner**	3 Hours	600	1800
8.	**Other Miscellaneous**	-	-	200
	Total (excluding cost of seed)			11070
	Cost of cultivation for Danteshwari			11730
	Cost of cultivation for MTU-1010			11829
	Cost of cultivation for Kranti variety			11796

(B) Estimation of common cost in plantation and management of Shisham :

Sl. No.	Particulars	Rate	Amount (Rs.)
1.	Cost of seedling	400 Nos@ Rs 5	2000
2.	Cost of digging pits, filling of pits with FYM and irrigation for 2 year.	400 Nos@ Rs 10	10000
3.	Tending operation 2 times in 1st year	Rs 5/ tree	2000
4.	Irrigation 1st and 2nd year during (12 irrigation during the year) 12 irrigation @ of Rs. 400/irrigation	12 irrigation @ of Rs. 400/irrigation and labor cost	4900
5.	Miscellaneous Expenditure up to 16th year	Rs 4500 per year	72000
	Total Expenditure up to 18 year	-	90900
	Average expenditure/year	-	5050
	Pruning cost (present year)	2 labour Rs.200/labour for 4 days	1600
	Total expenditure present year with pruning cost	-	6650

Appendix-4

Economic analysis of different treatments on per hectare area basis

Treatments	**Gross monetary return (Rs ha^{-1})**					**Cost of expenditure (Rs ha^{-1})**				**Net monetary return (Rs ha^{-1})**
	Crop		Tree		Total	Crop	Tree		Total	
	Grain	Straw	Pruned biomass	Stand biomass		Common	Plantation tending	Pruning		
No pruning V1	10903	2789		52119	65812	11730	5050		16780	49032
No pruning V2	19988	4033		40384	64406	11829	5050		16879	47527
No pruning V3	13069	5537		44405	63011	11796	5050		16845	46165
Tree alone (No crop)				39663	39663		5050		5050	34613
25% pruning V1	11526	2947	3233	51899	69605	11730	5050	1600	18380	51225
25% pruning V2	19029	5268	3256	63886	91441	11829	5050	1600	18479	72962
25% pruning V3	14069	4340	3580	47201	69190	11796	5050	1600	18446	50744
Tree alone (No crop)			3086	62851	65937		5050	1600	6650	59287
50% pruning V1	14613	3736	3871	35381	57602	11730	5050	2400	19180	38422
50% pruning V2	24486	8916	3406	49348	86159	11829	5050	2400	19279	66880
50% pruning V3	28883	6782	3886	40559	80111	11796	5050	2400	19246	60865
Tree alone (No crop)			3550	32477	36028		5050	2400	7450	28578
75% pruning V1	20138	5151	4120	19155	48565	11730	5050	2800	19580	28985
75% pruning V2	26986	8508	4276	26325	66095	11829	5050	2800	19679	46416
75% pruning V3	27554	7470	3982	11220	50226	11796	5050	2800	19646	30580
Tree alone (No crop)			3460	11220	14680		5050	2800	7850	6830
Open crop only -V1	18465	4723			23189	11730			11730	11459
Open crop only-V2	28251	10772			39023	11829			11829	27194
Open crop only-V3	34884	7826			42710	11796			11796	30914

Appendix-2

Mean sum of square for different morphological characters and biomass of Shisham

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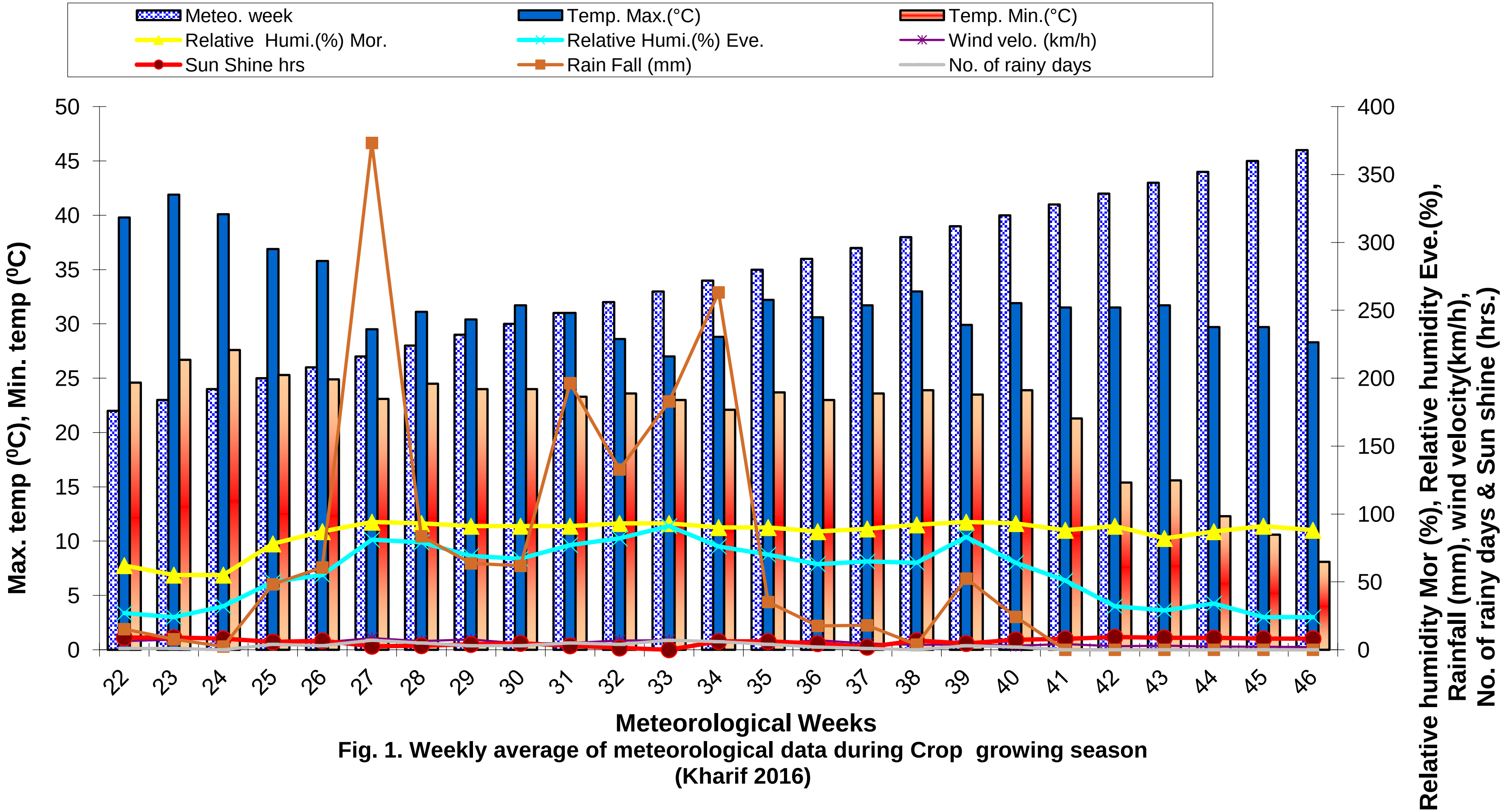
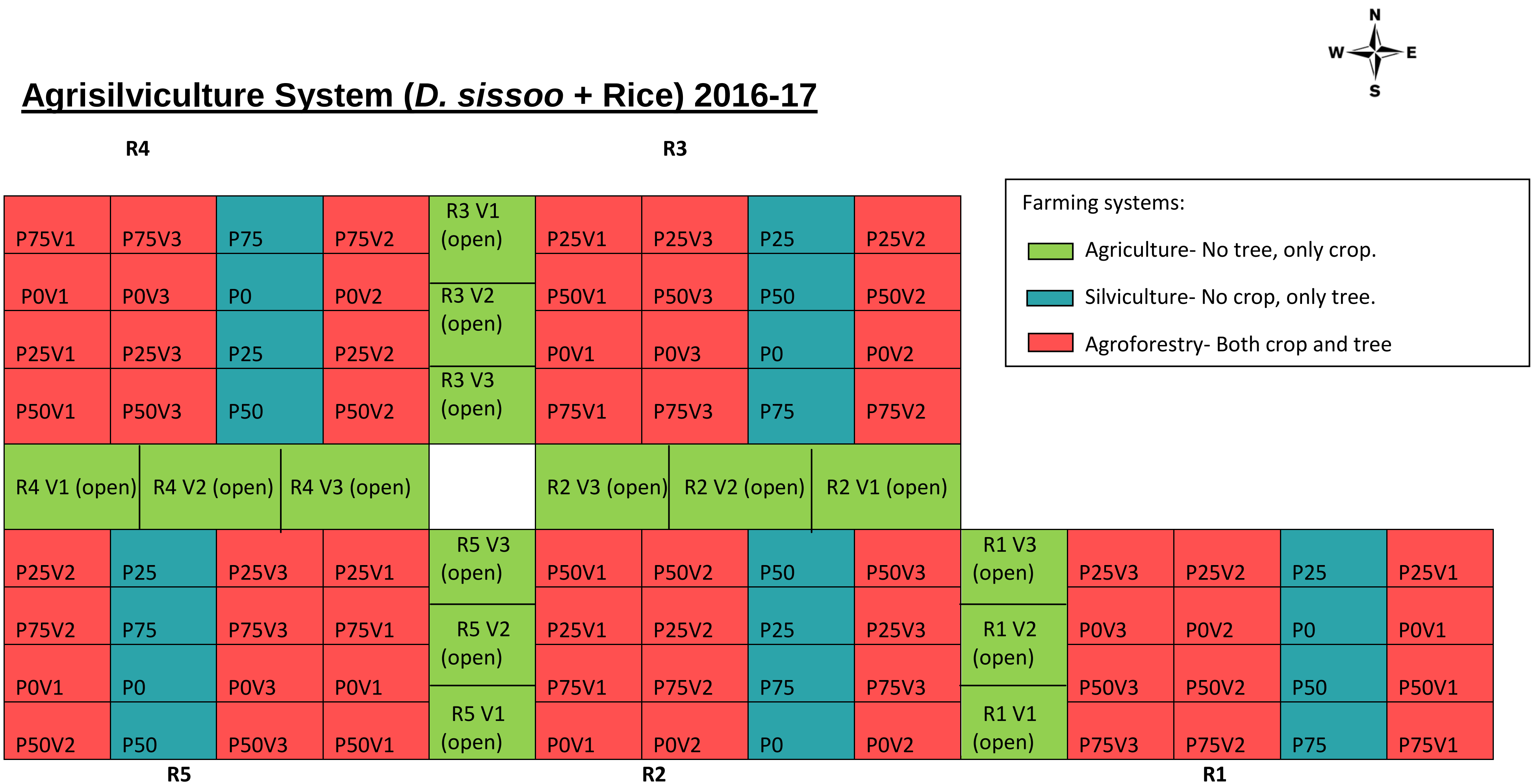


Fig. 1. Weekly average of meteorological data during Crop growing season (Kharif 2016)

Fig.1 : Meteorological information (week wise) during the entire crop season of the year (2016) Jabalpur

Agrisilviculture System (*D. sissoo* + Rice) 2016-17



Main treatment: 5 (4 pruning + 1 open)
P_0 – No pruning
P_{25} – 25% pruning
P_{50} – 50% pruning
P_{75} – 75% pruning
Open – crop only

Sub-treatment: 3 varieties
V1- Danteshwari (early duration: 90-95 days)
V2- MTU-1010 (medium duration: 100-110 days)
V3- Kranti (late duration: 120-135 days)
Gross plot size- 5m × 5m.
Net plot size- 4.2m × 4.2m.

Fertilizer application- 100:60:40::N:P:K kg/ha
Seed rate: 100 kg/ha.
Row to row spacing of paddy: 20cm
Tree spacing: 5m ×5m.

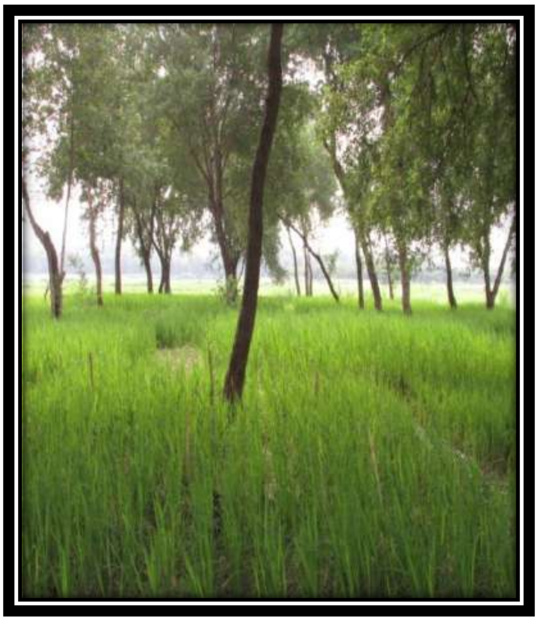
Figure 2: Layout plan of experimental field.

Plate 1. An overview of the experimental field.

***D.sissoo*(no pruning) +Danteshwari**

***D.sissoo*(25% pruning) +kranti**

***D.sissoo*(50% pruning)+MTU-1010**



***D.sissoo*(75% pruning)+Kranti**

Plate 2. Performance of rice with D.sissoo (0%, 25%, 50% and 75% pruning)

Danteshwari

Kranti

MTU-1010

Plate 3. Performance of rice in open conditions

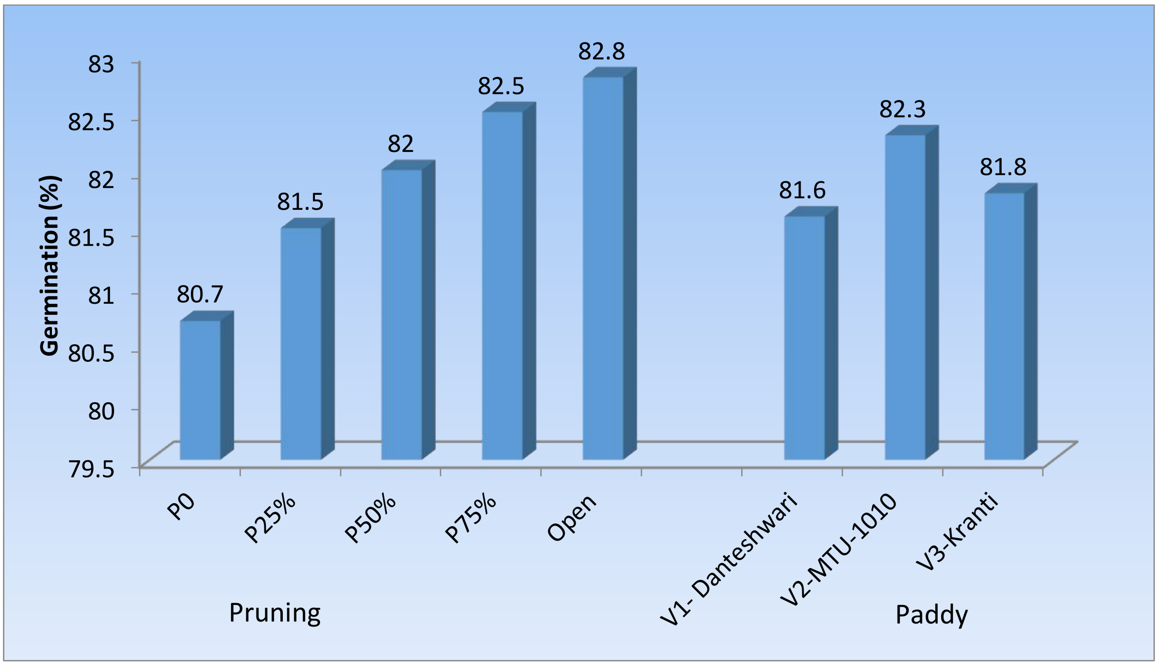


Fig 3: Effect of different pruning intensities in *Dalbergia sissoo* and rice varieties on germination percentage/MRL in agri-silviculture system.

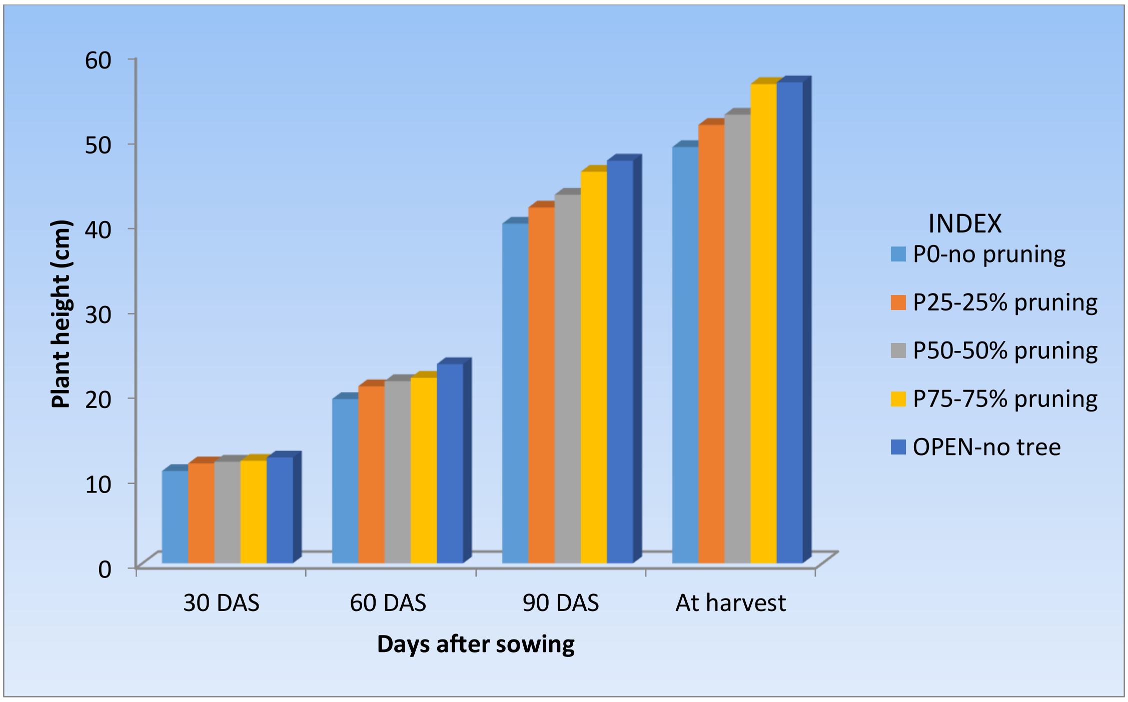


Fig 4(a): **Effect of pruning intensities in *D.sissoo* on plant height (cm) at 30, 60, 90 days after sowing and at harvest in agrisilviculture system**

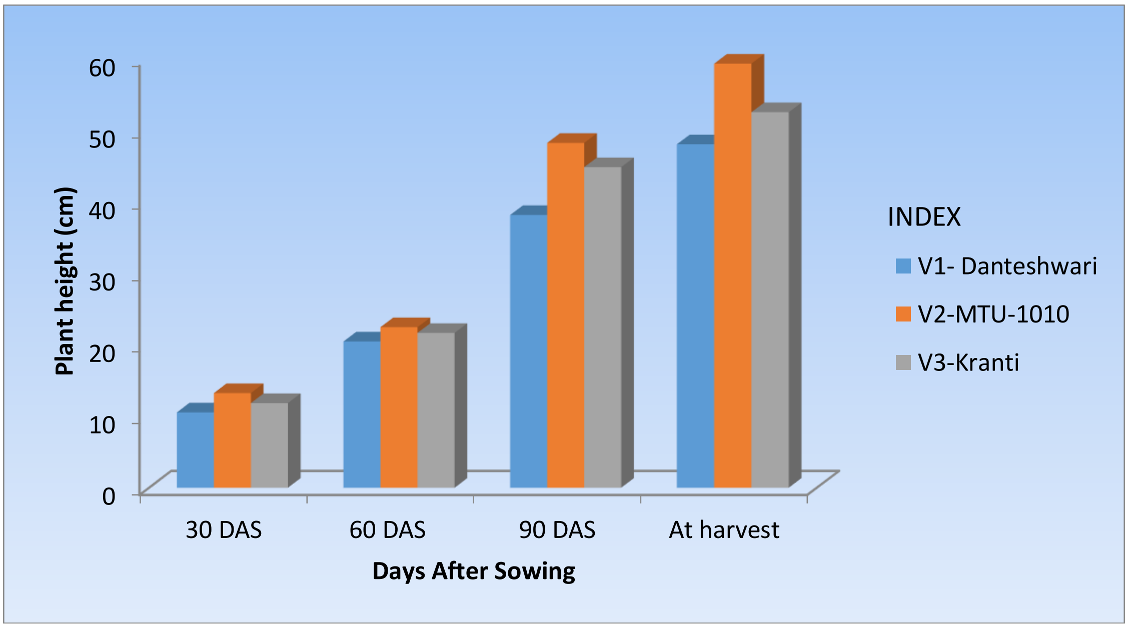


Fig 4(b): **Effect of different rice varieties on plant height (cm) at 30, 60, 90 days after sowing and at harvest in agri-silviculture system.**

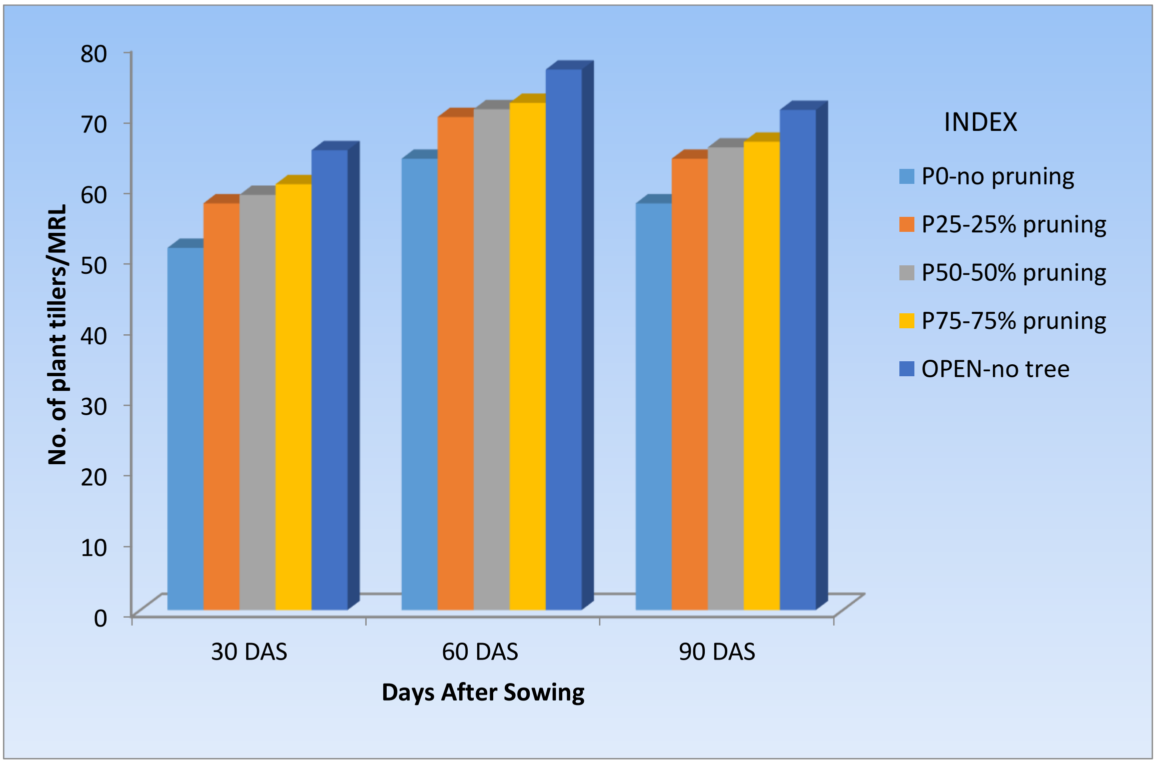


Fig 5(a): Effect of different pruning intensities in D.sissoo on number of tillers/meter row length at 30, 60, 90 days after sowing in agrisilviculture system

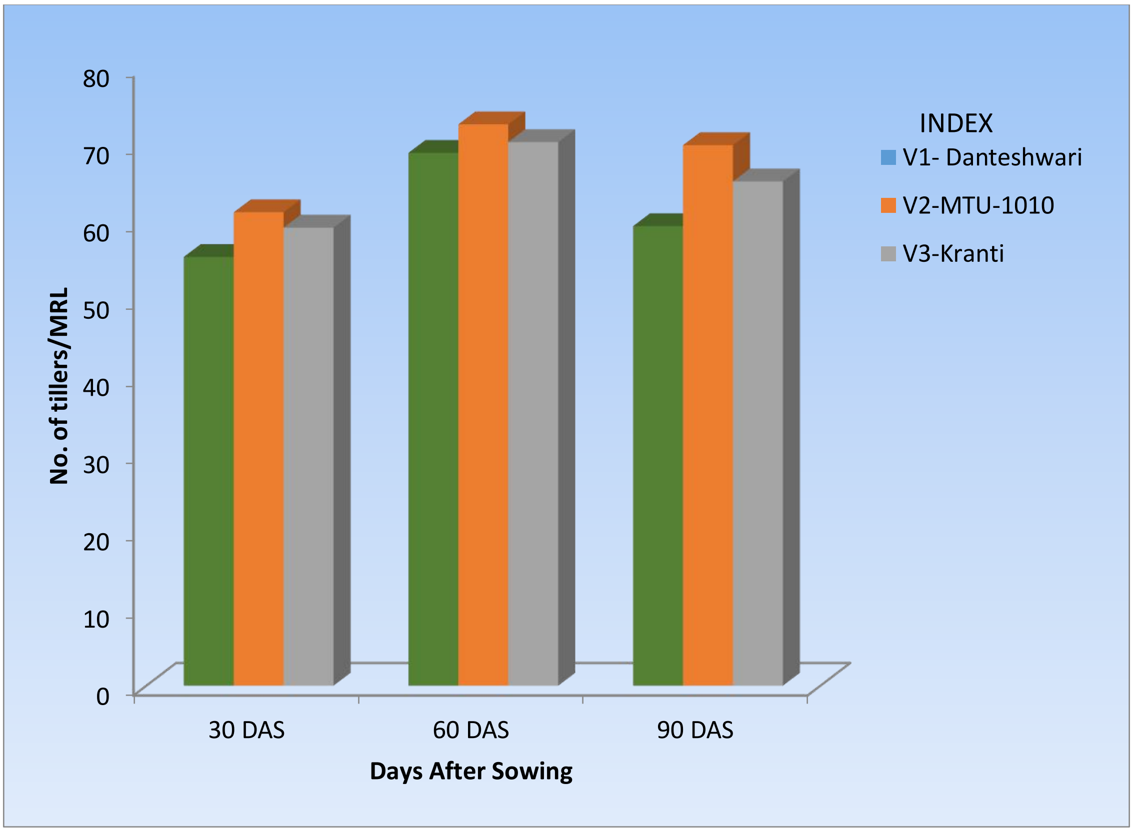


Fig 5(b): **Effect of different rice varieties on number of tillers/meter row length at 30, 60 and 90 days after sowing in agri-silviculture system**

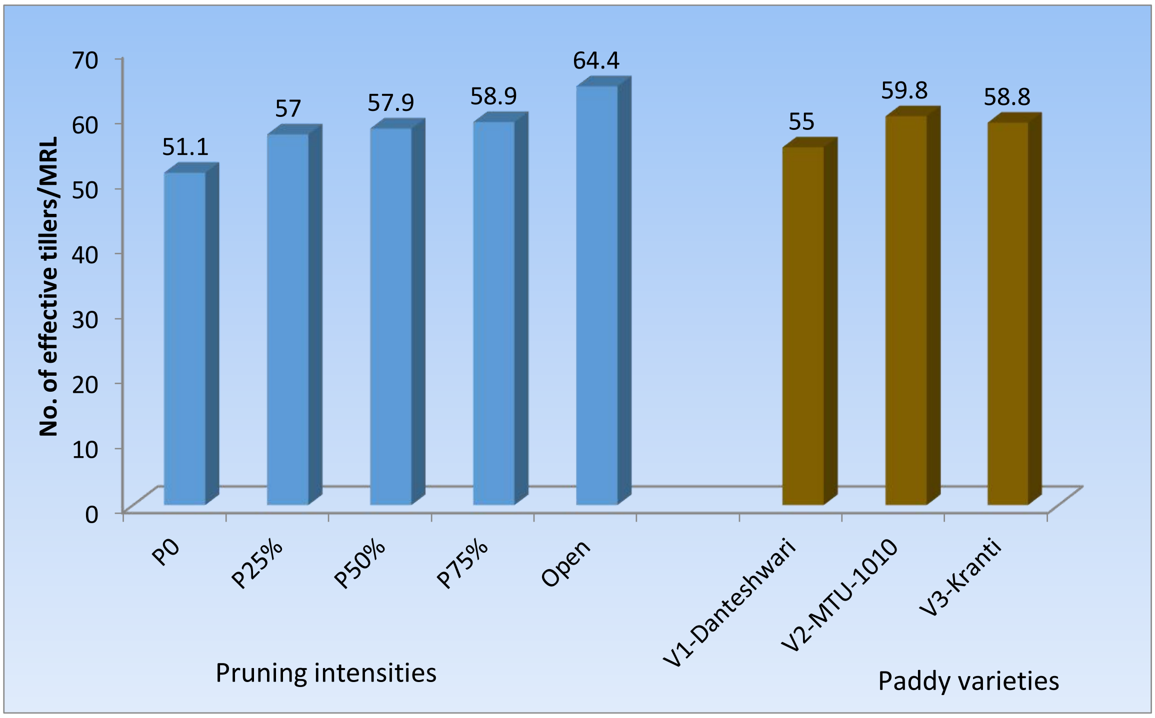


Fig 6(a): Number of effective tillers/MRL of rice as affected by different pruning intensities and rice varieties

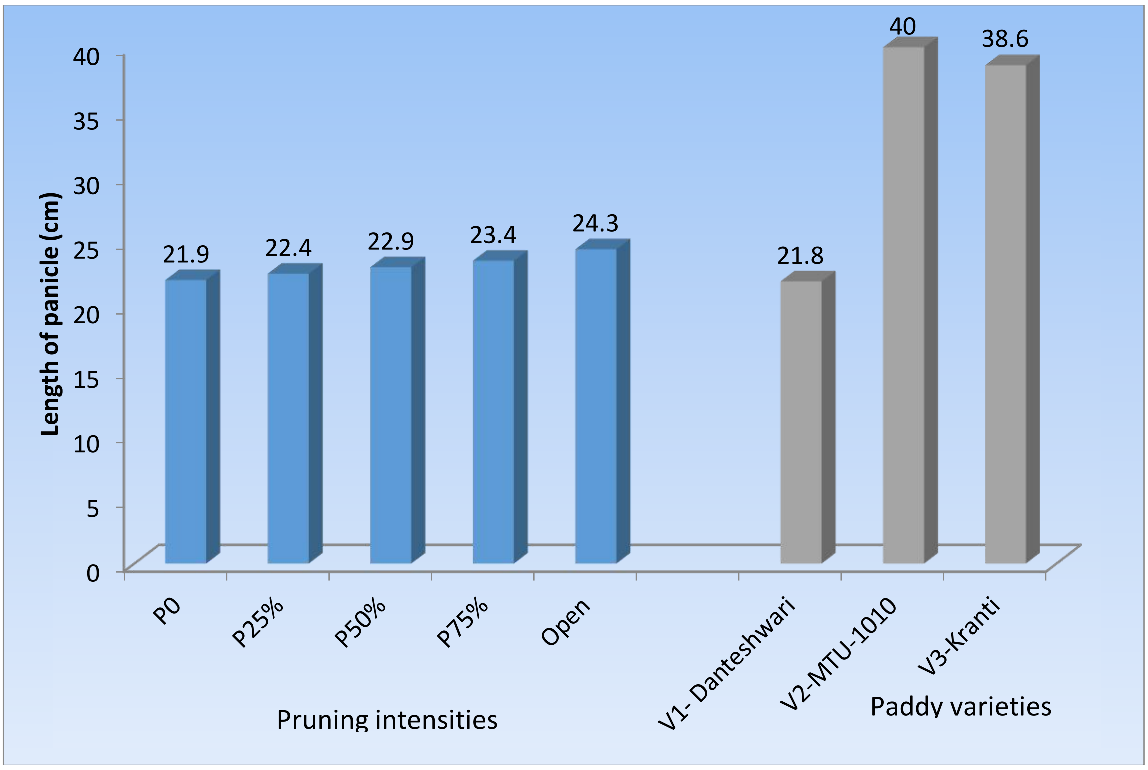


Fig 6 (b): Length of panicle (cm) of rice as affected by different pruning intensities and rice varieties

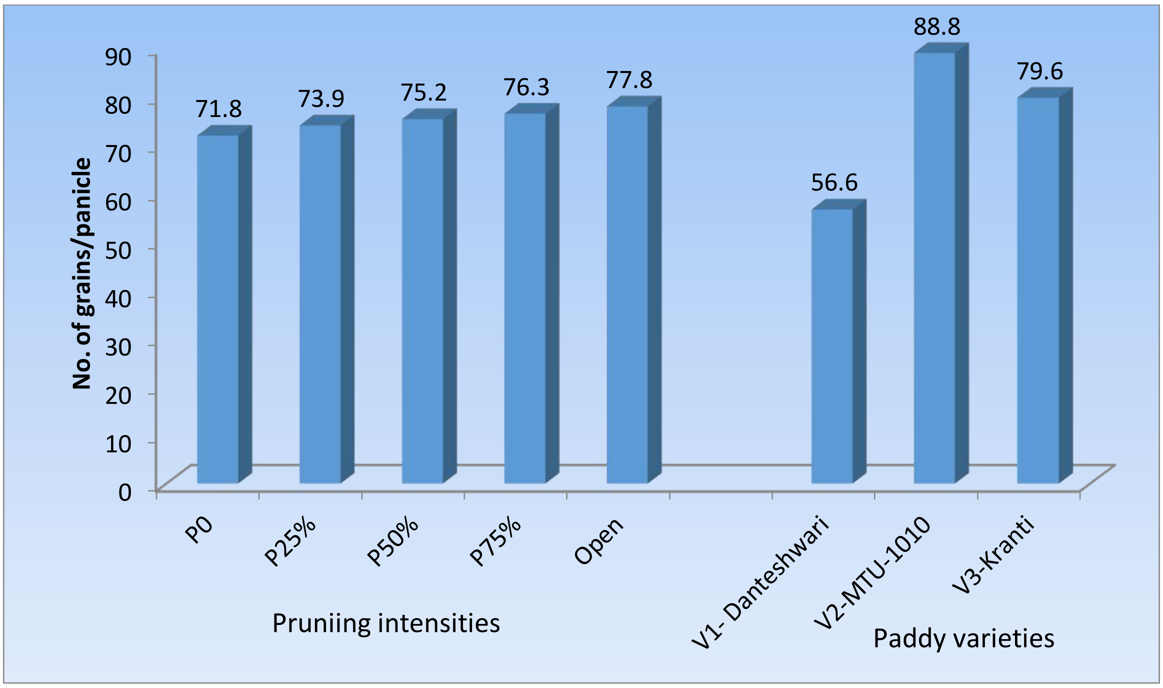


Fig 6(c): Number of grains/panicle of rice as affected by different pruning intensities and rice varieties

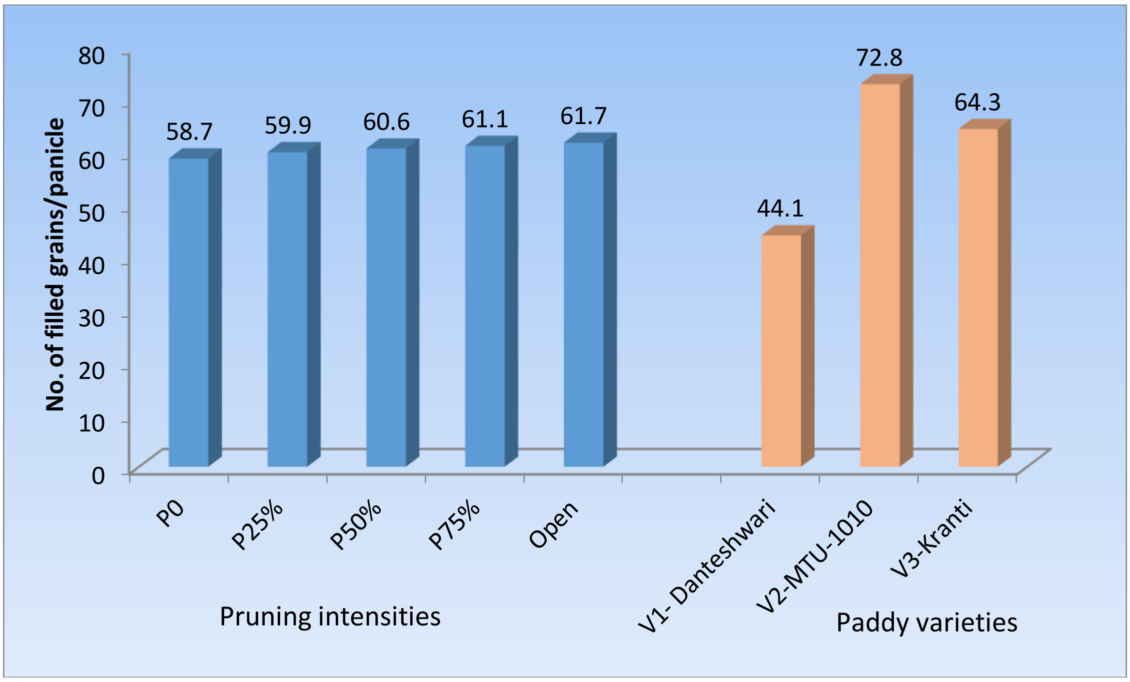


Fig 6(d): Number of filled grains/ panicle of rice as affected by different pruning intensities and paddy varieties

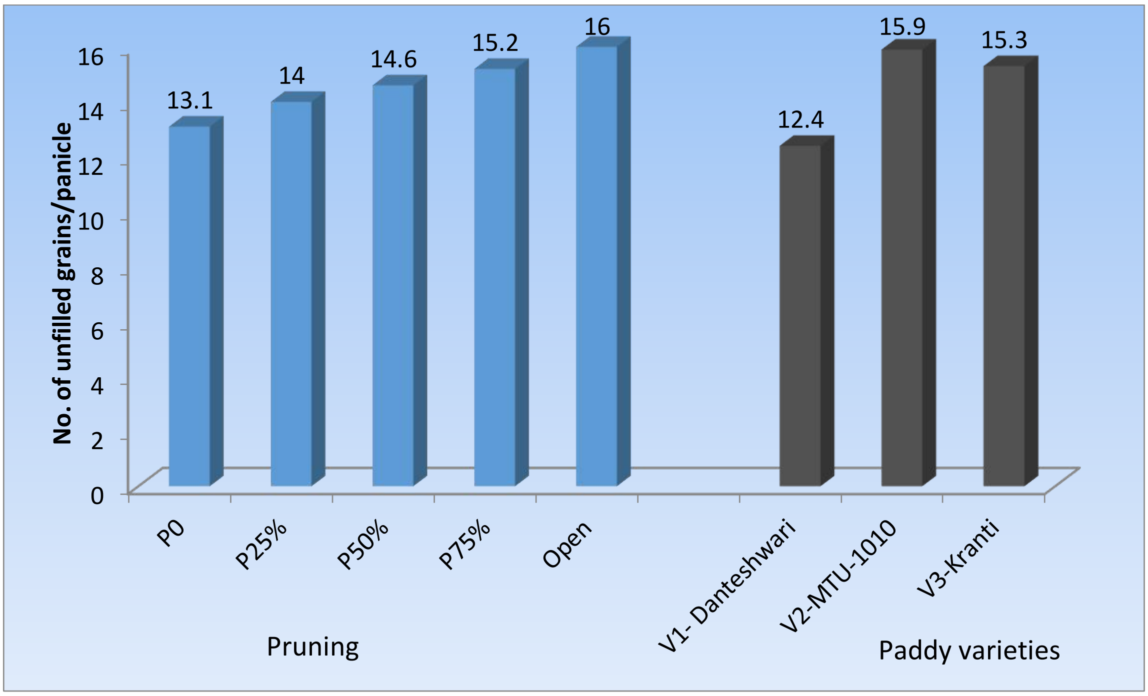


Fig 6(e): Number of unfilled grains/panicle as affected by different pruning intensities and paddy varieties

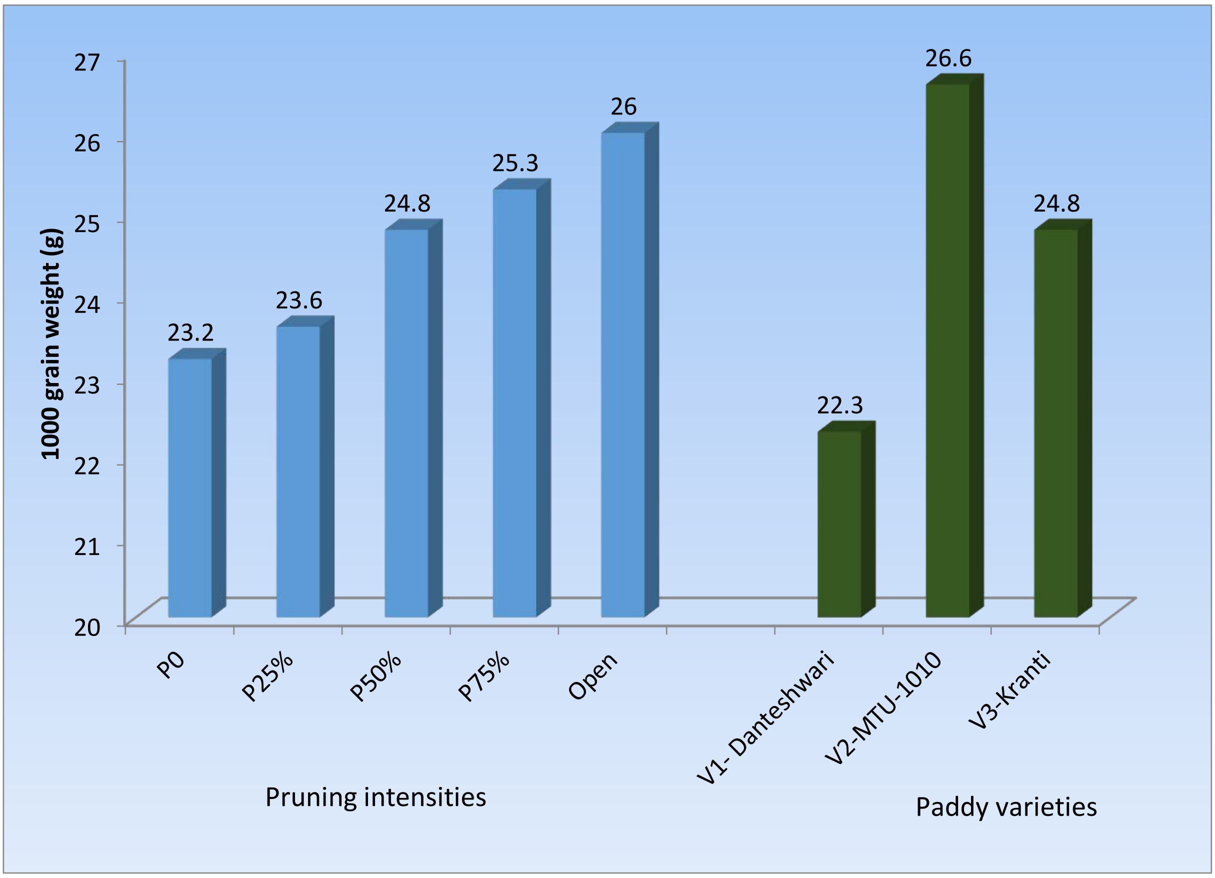


Fig 6(f): 1000 grain weight of paddy as affected by different pruning intensities and paddy varieties

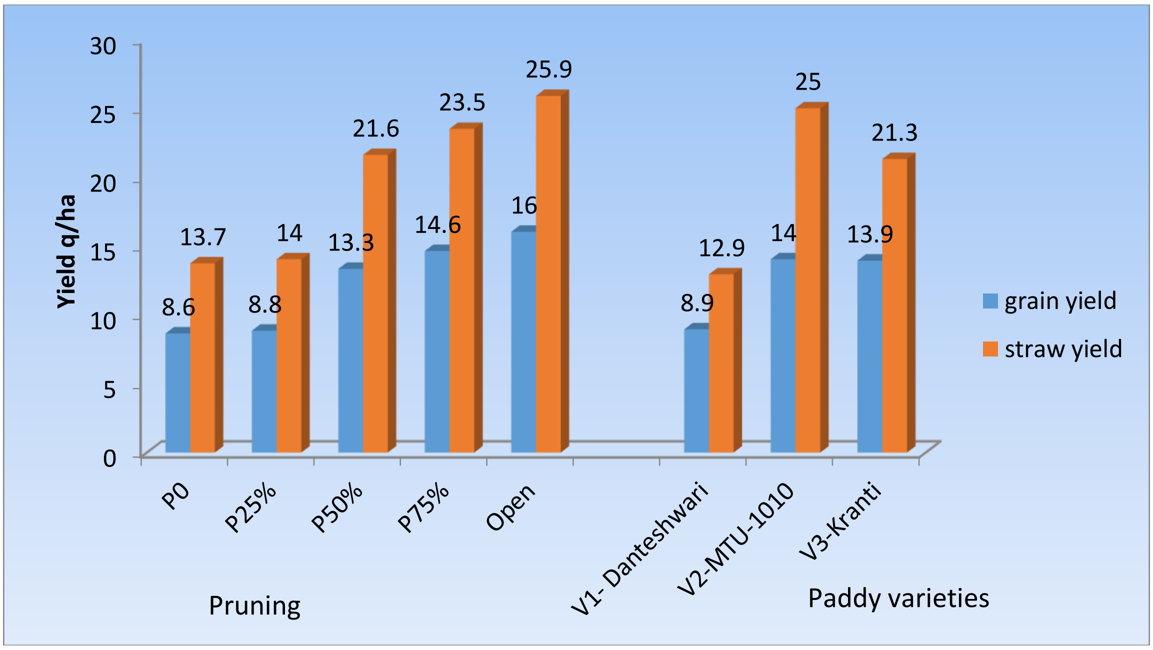


Fig 7: **Grain yield and straw yield of paddy as influenced by different pruning intensities and paddy varieties rate in agrisilviculture system**

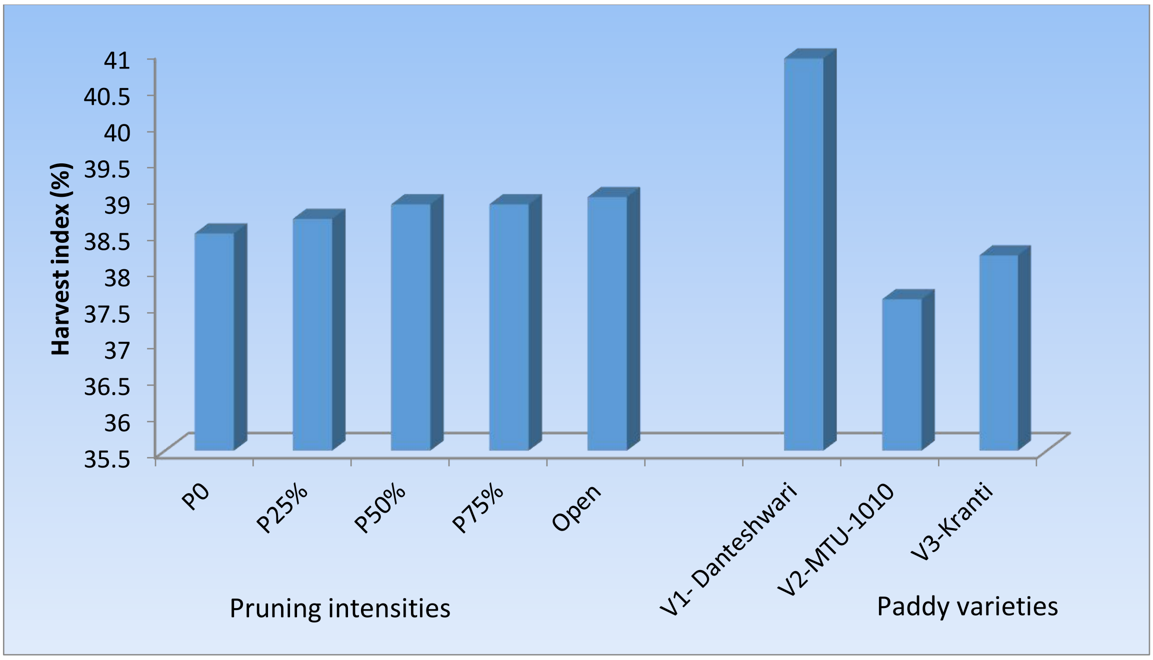


Fig 8: **Harvest index of rice as influenced by different pruning intensities and paddy varieties in agrisilviculture system**

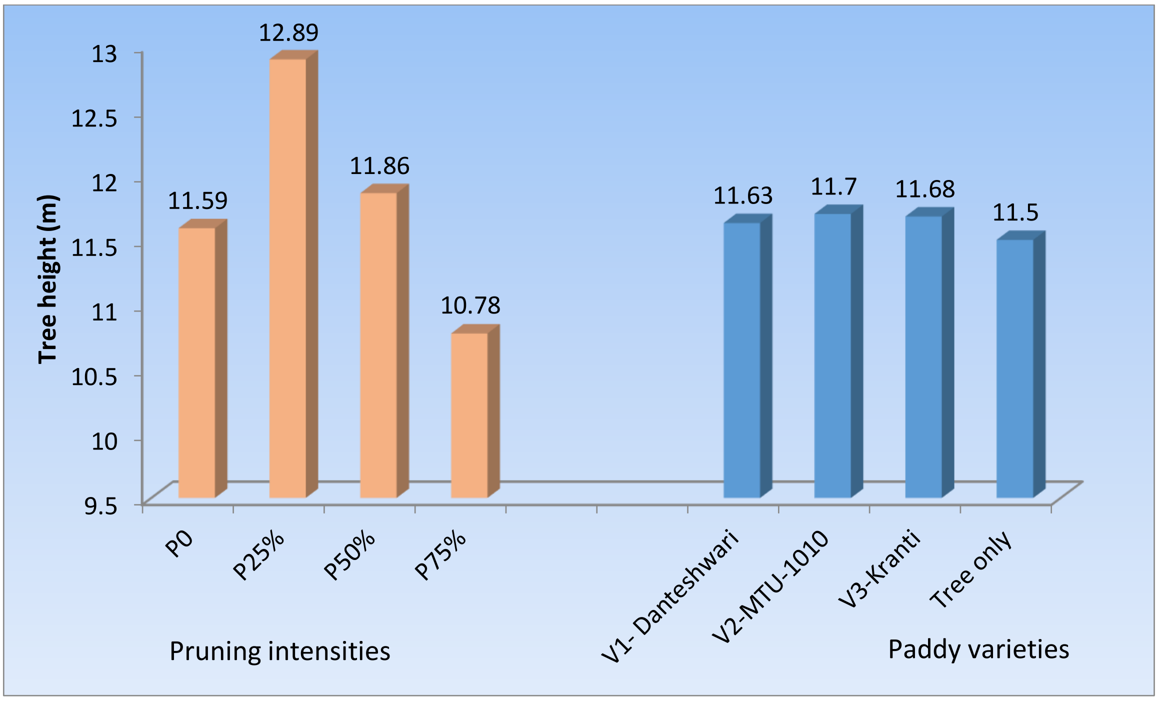


Fig 9: Effect of pruning intensities and rice varieties on tree height (m)

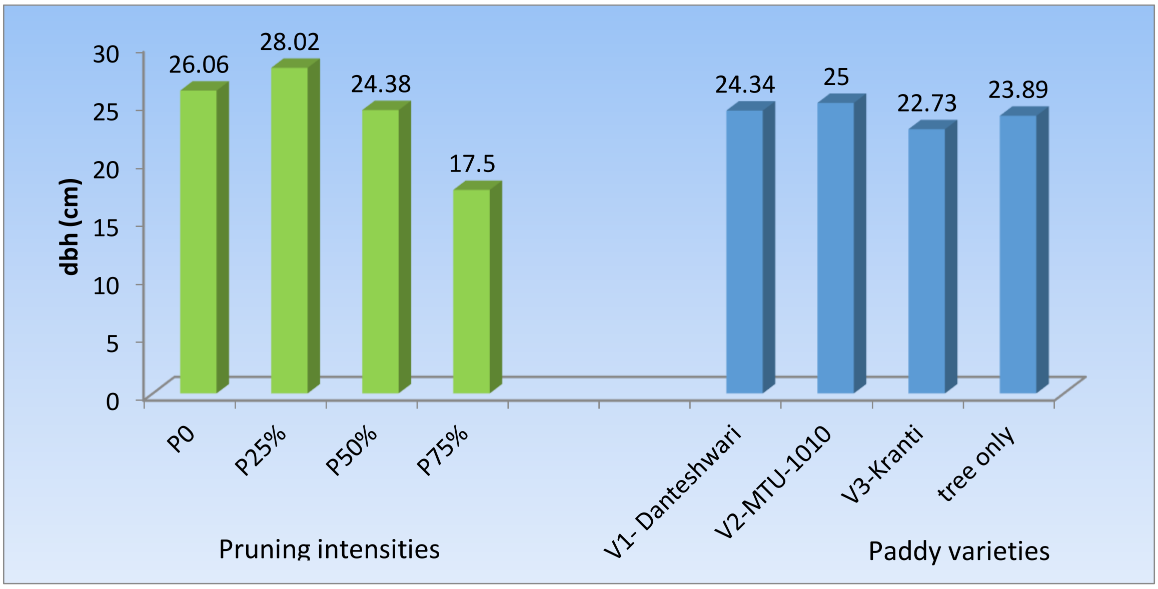


Fig 10: Effect of pruning intensities and rice varieties on DBH (cm) of *Dalbergia sissoo*

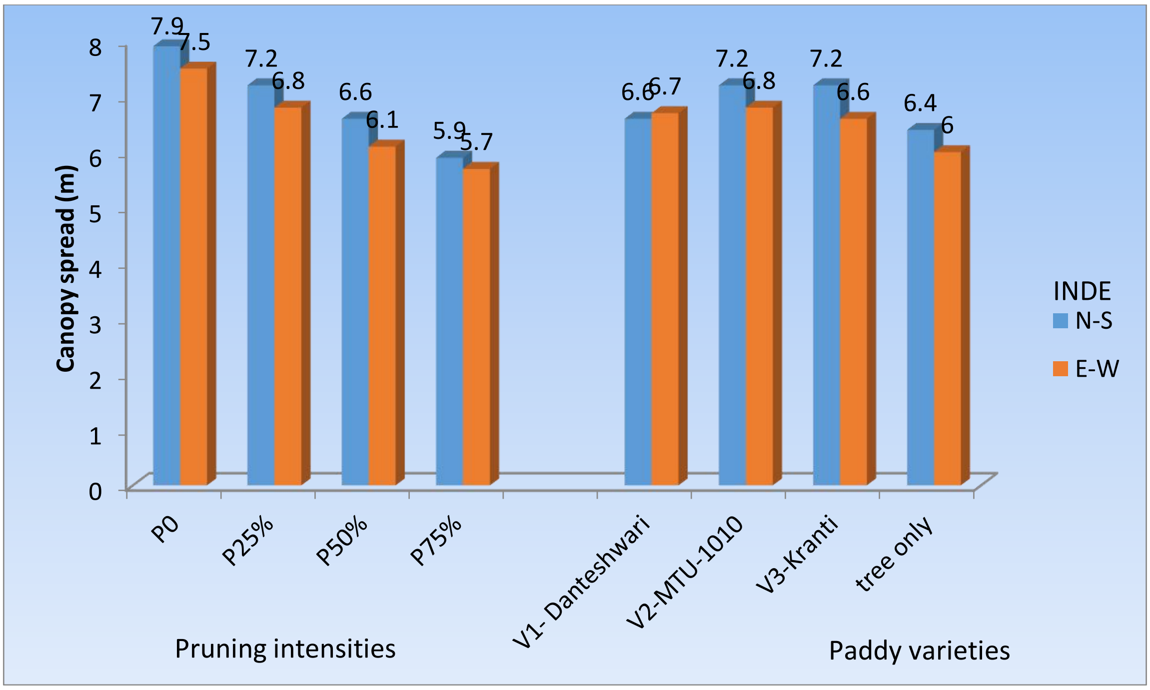


Fig 11: **Effect of pruning intensities and rice varieties on tree canopy spread N-S and E-W of *Dalbergia sissoo***

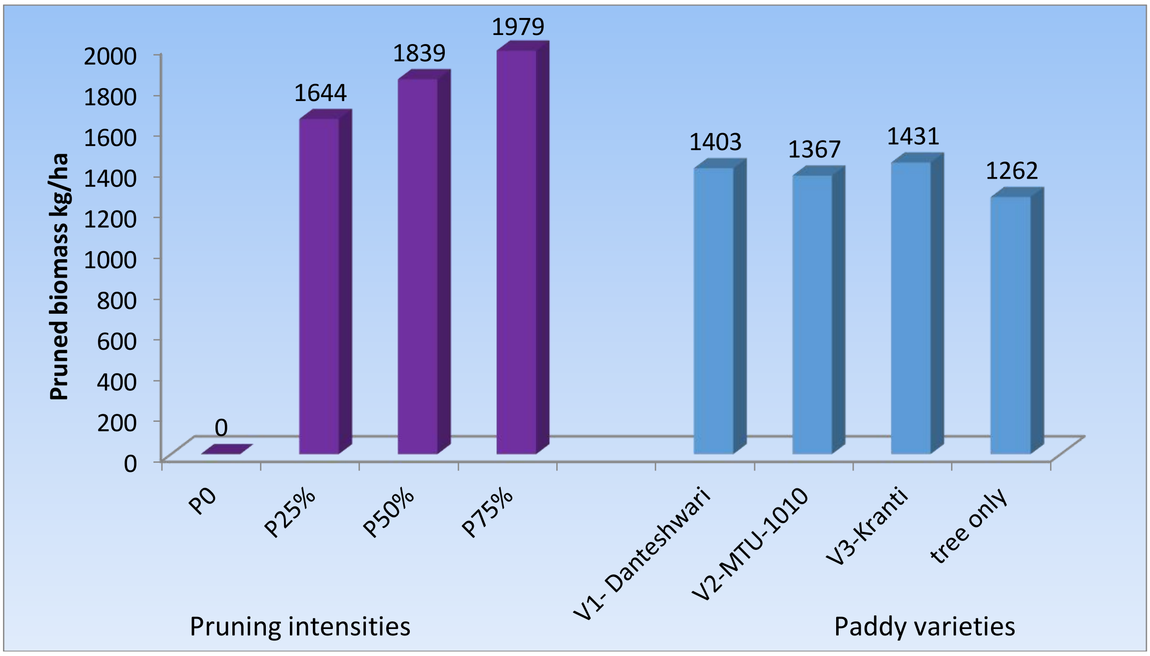


Fig 12: **Effect of pruning intensities and rice varieties on pruned biomass (kg/ha)**

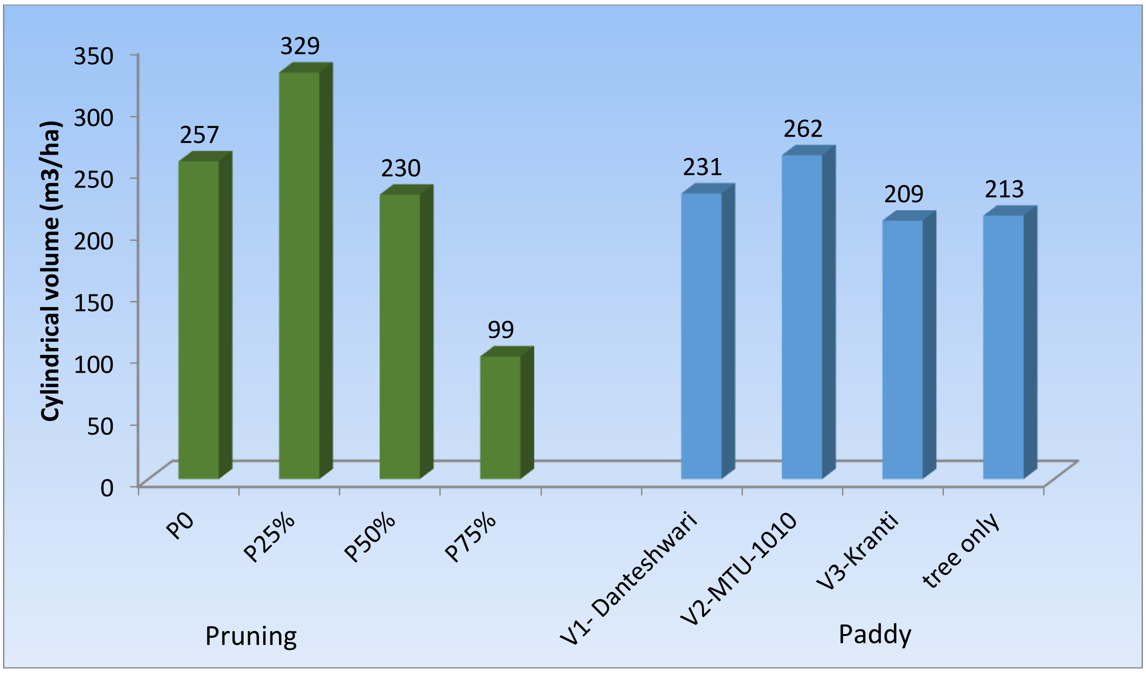


Fig 13: **Effect of different pruning intensities and rice varieties rate on cylindrical volume (m^3 ha^{-1}) of *D. sissoo***

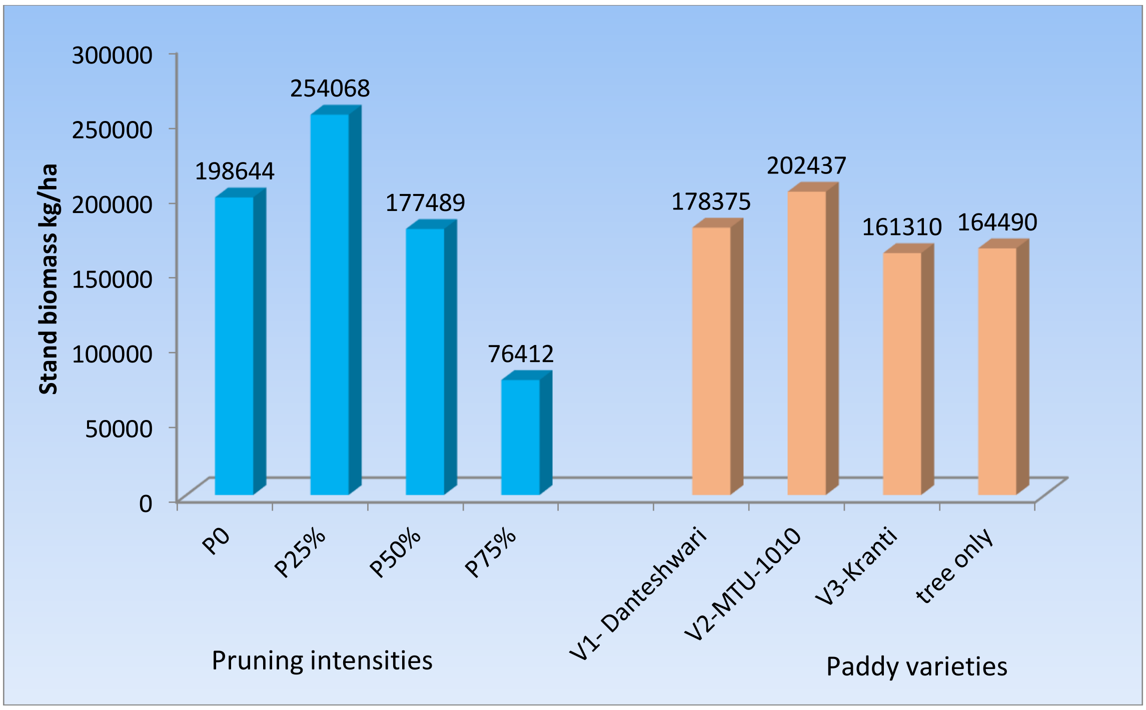


Fig 14: **Effect of different pruning intensities and rice varieties on stand biomass (kg ha^{-1}) of *D. sissoo***

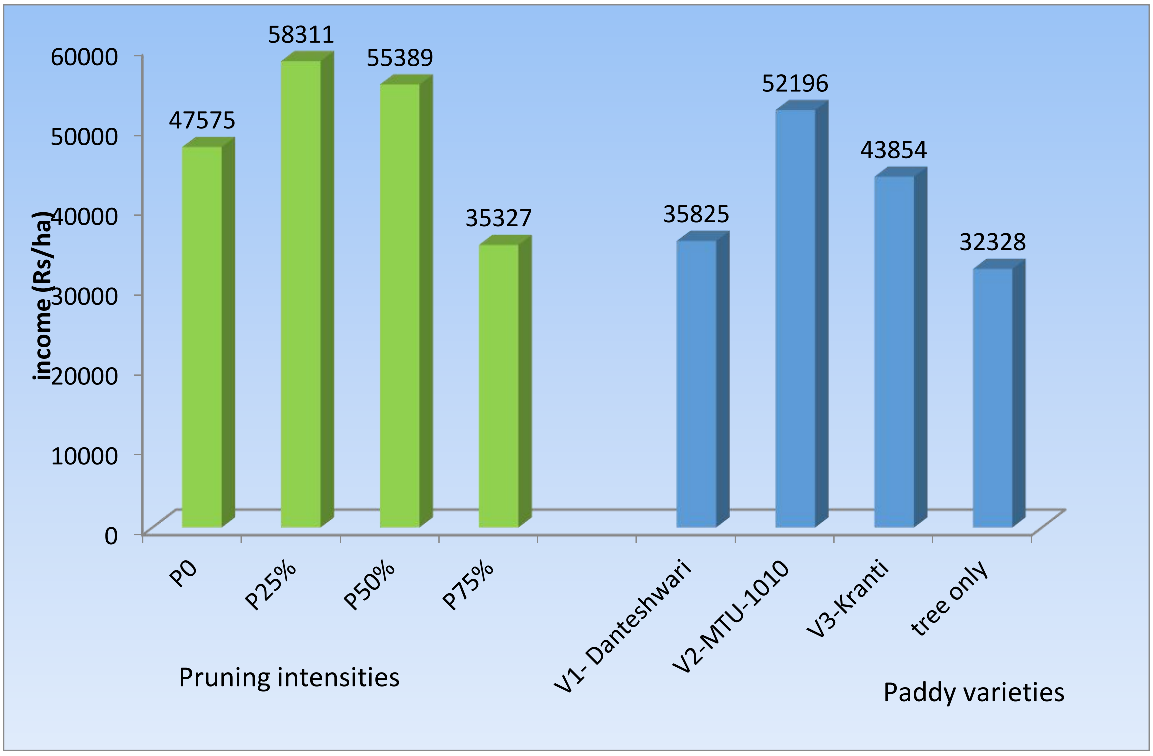


Fig 15: **Net monetary return (Rs. ha^{-1}) of the system**

CURRICULUM VITAE

The author of this thesis **Allana Francesca Marak** was born on 15th January 1992 at New Tura, West Garo Hills, Meghalaya. Author has passed 10th class with 80.3 percentage in 2009 and 12th class with 60.2 percentage. Then the author joined B.Sc. Forestry programme in 2011 at Dolphin (P.G.) Institute of Biomedical and Natural Sciences, HNBGU, Dehradun, Uttarakhand. She successfully completed and graduated with a percentage of 73.4.

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