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Agroforestry Synergy: Maximizing Oat Performance in Semi-Arid Haryana through *Melia dubia* Intercropping

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ABSTRACT

An experiment was conducted in a farmer's field located in the village Gillan Khera, situated in the western semi-arid region of Haryana's Fatehabad district during the Rabi season of 2021-22. The aim was to assess the performance of three oat varieties (OS-6, OS-7, and OS-403) within a 7-year-old Melia dubia plantation with a spacing of 3m × 3m. The mean values of various tree growth parameters such as tree height (17.8 m), diameter at breast height (59.5 cm), and canopy spread (8.5 m) were found to be higher in agroforestry rather than in the pure stand of Melia dubia after harvest of the crop. Plant growth parameters and yield attributes exhibited significantly higher in open conditions compared to those under the plantation. Among the oat varieties, OS-403 exhibited superior growth traits in all evaluated parameters. Oat variety OS-403 showed the maximum green fodder and dry fodder yields. Significant increases were observed in parameters such as plant height at different growth stages, number of tillers per meter row length, leaf stem ratio, and leaf area index in OS-403. Conversely, OS-6 showed lower growth parameters and yield in both conditions. Light intensity shows an increase throughout the day, reaching its peak at 2:00 p.m. under both conditions. For example, at 2:00 p.m., light intensity rises from 515.5 lux (30 DAS) to 934.9 lux (maturity) in the average values. The reduction in yield with decreasing spacing may be attributed to the shading effect of trees on crops. However, the long-term accumulation of wood from trees is expected to yield greater economic returns in the future.

Keywords: *Melia dubia, Agroforestry, Canopy Spread, Oat Varieties, Growth Parameters, Leaf Stem Ratio, Leaf Area Index, Light intensity*

1. Introduction

Agroforestry, the integration of trees and shrubs with crops and livestock, aims to create sustainable and productive agricultural systems. This approach enhances biodiversity, soil fertility, and water conservation while providing multiple outputs such as food, fuel, and timber. In India, agroforestry has gained prominence for its role in improving rural livelihoods and environmental sustainability. [16] highlight the benefits of agroforestry in enhancing soil health, sequestering carbon, and supporting biodiversity. Agroforestry systems are particularly effective in semi-arid regions of India, where they help mitigate the impacts of climate change and land degradation. Various research is being carried out in multiple directions to strengthen the impact of agroforestry on agricultural environment. Trees on agricultural lands are capable of solving a number of complications of agricultural systems for example sustainable biological production, deforestation, declining soil fertility, occurrence of droughts and increasing use of dangerous chemicals [1]. The diversification of the farm system into an agroforestry system can increase agricultural productivity, improve soil fertility, control erosion, conserve biodiversity, and diversify income for households and communities [3].

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Melia dubia Cav., a tree native to tropical and sub-tropical regions, is primarily cultivated for its industrial and medicinal value. Commonly referred to as "Malabar Neem," "Maha Neem," "Gora Neem," and "Barma Dek," this tree belongs to the *Meliaceae* family. It grows in a variety of soils such as deep fertile sandy loam soils and shallow gravelly soils. *Melia dubia* is drought-tolerant in nature. It grows well at annual temperatures of 23-27°C and altitudes up to 1800 m. It does well in moist regions, with annual rainfall ranging from 750-1500 mm [11]. It grows in well-drained red, red loam and black loam soils with a pH range of 5.5 to 7 and depth of 50 to 150 cm, requires moderate soil fertility and can come up in soils with salinity of <4ds/m [29]. It is a deciduous tree and remains leafless from December to February. *Melia dubia* (Malabar neem) possesses anti-cancer, anti-diabetic, anti-tumor, anti-inflammatory, antioxidant, antibacterial, antiviral and fungicidal properties [20;28]. [27] observed that *Melia dubia* can be grown in most of the areas in Haryana and this tree species which is indigenous would be a promising alternative option to *Poplar* and *Eucalyptus.* Besides this, the *Melia dubia* tree can be a profitable option for the utilization of degraded ravine lands.

Oat (*Avena sativa* L.) belonging to the family *Poaceae* is a cereal crop. Oat as fodder and grain is a good source of protein, fiber and minerals. It is used as a green crop and silage for animals. Oats grow well on sandy loam to heavy clay soils with good drainage. On acid soils, oats perform better than other small-grain cereals.

Saline soils are not suitable. Oat can provide nutritious and palatable fodder, grown in the winter season in North-Western and Central India and now extended to the Eastern region also [22]. Oats have emerged as a valuable crop in agroforestry systems due to their adaptability, nutritional benefits, and positive impacts on soil health. Agroforestry, which integrates trees, shrubs, and crops, aims to create sustainable and productive agricultural landscapes. Oats significantly contribute to soil health by improving soil structure, organic matter content, and water infiltration. Their robust root systems prevent soil erosion and enhance soil aeration, essential for maintaining fertile and productive land [19]. Additionally, oats act as a nutrient catch crop, absorbing residual nitrogen and other nutrients, thus minimizing leaching and increasing nutrient availability for subsequent crops [26]. The allelopathic properties of oats make them effective in weed suppression, reducing the need for chemical herbicides and promoting sustainable farming practices [14]. This characteristic is particularly beneficial in agroforestry systems, where maintaining ecological balance is crucial. Oats also support biodiversity and ecosystem services within agroforestry systems. They provide habitat and food sources for various organisms, enhancing ecosystem resilience and functionality. This biodiversity supports essential services like pollination and natural pest control, contributing to the overall health and productivity of the agricultural system [4]. Recent research in India underscores the potential of oats in agroforestry to improve soil health, enhance nutrient management, and support sustainable agricultural practices [18;19;25].

2. Material and Method

2.1 Site description

The field experiment was carried out during 2021-2022 in the semi-arid region of Haryana, specifically at a farmer's field in Gillan Khera village, Fatehabad district. The experimental site was located at 29˚50' latitude and 75˚30' longitude, with an elevation of 212 m above sea level. The area experiences a subtropical-monsoon climate, with an average annual rainfall of 360-400 mm, predominantly occurring from July to September. During the summer months of May and June, the region faces high temperatures ranging from 40 to 45 °C, while in December and January, winter temperatures can drop to 0 °C. The mean monthly values of weather parameters obtained from the meteorological observatory situated nearest to the research site during research are depicted in Fig. 1.

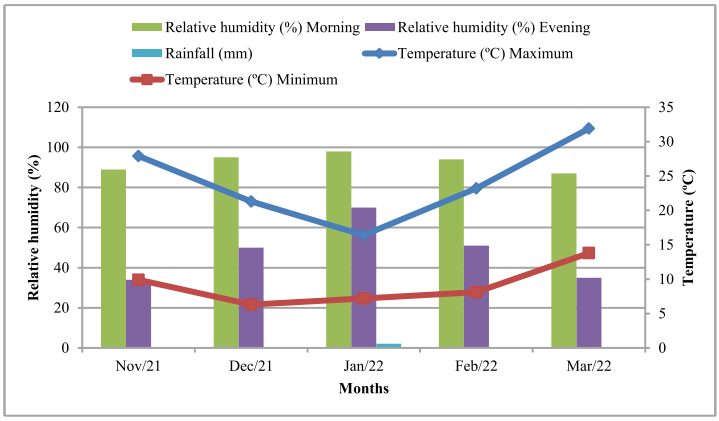

Figure 1: Monthly weather data of site of the experiment from November 2021 to March 2022

2.2 Details of the experiment

The investigation was carried out within an established seven-year-old *Melia dubia* plantation where oat crops are grown in the spaces between the trees in Gillan Khera village, Fatehabad district, Haryana.

Tree species - Burma Dek (*Melia dubia Cav.)*
Spacing - 3 m X 3 m
Crop - Oat (*Avena sativa*)
Season - Rabi (2021-22)
Oat Varieties

- OS-6
- OS-7
- OS-403

Experimental Design – Randomised Block Design (RBD)
Replications–3

The recommended package of practice of CCS Haryana Agricultural University will be followed both in *Melia dubia* and oat varieties combination as well as in control condition.

2.3 Data collection

2.3.1 Growth studies of *Melia dubia* Cav. At the initial and harvest stages of the experiment

The DBH, tree height, and canopy spread were recorded following the standard rules from *Melia dubia* plantation prior to and after harvest of oat varieties. Circumference (C) of *Melia dubia* trees was measured at 1.37 m height from the ground level and converted into DBH by using the relationship between two i.e. (dbh = C/π). Measurements were carried out with measuring tape (cm). The height of the trees was calculated with the help of a clinometer and expressed in meters. The average values of crown spread in north-south and east-west directions were calculated and expressed in meters at sowing time and after harvesting of agricultural crops [12].

2.3.2 Plant height (cm) at 30, 60 DAS and at harvest

Five plants from each replication of all three varieties were tagged at random and measured at 30, 60 DAS and at harvest time for height. Height was taken using a centimeter scale and was measured from the base of the plant up to the tip of the leaf.

2.3.3 Leaf area (cm^2/m^2)

Leaf area was calculated at 30, 60 DAS and at harvest. Leaf-blades were separated from the freshly removed shoot, and the area of leaves was recorded with the help of the CI-202 Portable Lasar Leaf Area Meter. Leaf area is measured in cm^2.

2.3.4 Leaf area index

The average leaf area per unit time area was computed for the leaf area index (LAI). LAI is the ratio between the surface area of green leaves to the ground area covered.

$$\text{Leaf area index} = \frac{\text{Leaf area}}{\text{Ground area}}$$

2.3.5 Leaf stem ratio at each cut 30 DAS, 60 DAS and at harvest.

Five plants from each replication of all three varieties were randomly taken from each plot at 30, 60 DAS and at harvest. Then their stems and leaves were separated and weighed to work out the leaf-stem ratio.

2.4 Yield attributes

2.4.1 Green fodder yield

The crop was harvested and the green fodder yield of the individual plot was weighed separately. The yield was recorded just after harvesting with the help of spring balance and yield per hectare was computed.

2.4.2 Dry matter yield

At harvest, a random sample of 500 g green fodder was taken from each plot in a paper bag dried in the sun, and then transferred into an oven for final drying at a temperature of 65+5°C till the constant weight was achieved. Dry matter yield was calculated by multiplying dry matter content with total green fodder yield.

3. Result & Discussion

3.1 Oat plant height (cm)

The results of the present study showed (Figure 2) that the height of the oat crop was found higher in the fields without trees than under the canopy of *Melia dubia* trees. It could be due to the tree crop competitive interaction which led to lower photosynthetic activity thereby sluggish cell division and cell elongation and consequently lower height of plants under trees. The findings of the present study agree with the results of [15]. OS-403 variety of oats performed better in terms of plant height without trees in the field or with trees revealing it as a potential genotype in intercropped conditions. The lower height of the OS-6 variety under plantation may be due to reduced light intensity under *Melia dubia*. Light intensity increases throughout the day, peaking at 2:00 p.m. under both conditions. Intensity also rises as the plants mature. For instance, at 2:00 p.m., light intensity increases from 515.5 lux (30 DAS) to 934.9 lux (maturity) in the mean values. The more light intensity in sole cropping helped in increasing the photosynthetic efficiency of oat varieties in sole conditions compared to agroforestry systems.[8] investigated wheat crops in the *Eucalyptus*-based agroforestry system and found a significant decrease in growth parameters of wheat crops under trees.

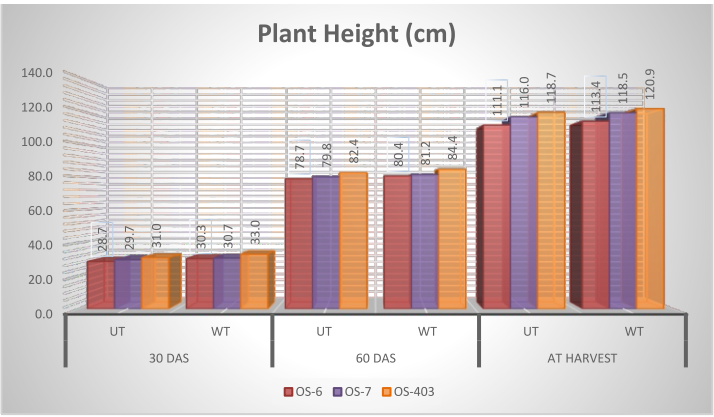

Figure 2: Plant height at 30, 60 DAS and maturity of oat varieties in under tree and control (field without trees) condition

3.2 Number of tillers

The number of tillers is recognized as a crucial determinant that markedly affected the oat yield. Generally, the higher numbers of tillers contribute to increased productivity of green fodder and dry matter yield of oats. The total number of tillers was significantly higher in the plots without trees than under trees. [17] reported that tree-crop competition for resources reduced the number of tillers in the crop. Oat variety OS-403 exhibited a significantly higher number of tillers among both environments. However, oat variety OS-6 recorded with significantly lesser number of tillers in both environments. The results revealed (Figure 3) that the total number of tillers of various oat varieties was significantly lesser in under-tree condition than without trees. The possible reason for the higher number of tillers in control (sole crop) could be due to the availability of higher light intensity for oat varieties in sole cropping conditions compared to under *Melia dubia* plantation. These results are in corroboration with the findings of [10]. They reported that the number of tillers in different wheat varieties was significantly higher in the sole crop in comparison to that of under *Poplar*-based agroforestry system. Corroborative findings to the statement have been reported by [2].

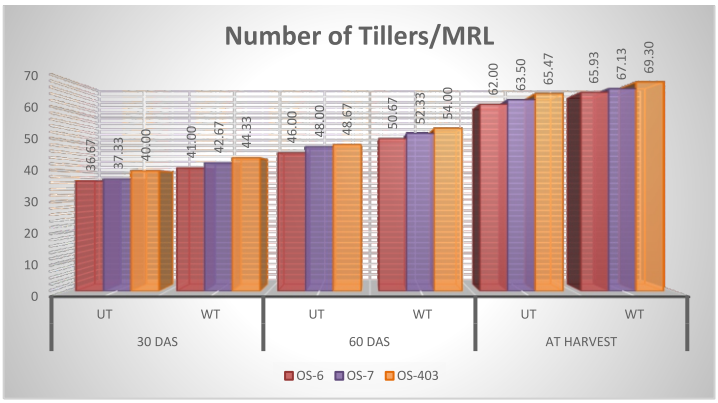

Figure 3: Number of tillers at 30, 60 DAS and maturity of oat varieties in under tree and control (field without trees) condition

3.3 Leaf stem ratio

It is evident from the data that leaf stem ratios were significantly affected by varietal characters and environment when recorded at harvest. Leaf stem ratio is recognized as a crucial determinant that markedly affects the oat yield. Generally, the higher leaf stem ratio contributes to increased productivity of green fodder and dry matter yield of oats. The leaf stem ratios were significantly higher in the field without trees than under trees. Oat variety OS-403 exhibited at par higher leaf stem ratio among both environments. The results revealed (Figure 4) that the leaf stem ratio of various oat varieties was significantly lesser under tree conditions than without trees. The possible reason for the higher number of leaf stem ratios without trees could be due to the availability of higher light intensity for oat varieties in sole cropping conditions compared to under *Melia dubia* plantation. These results are in corroboration with the findings of [9].

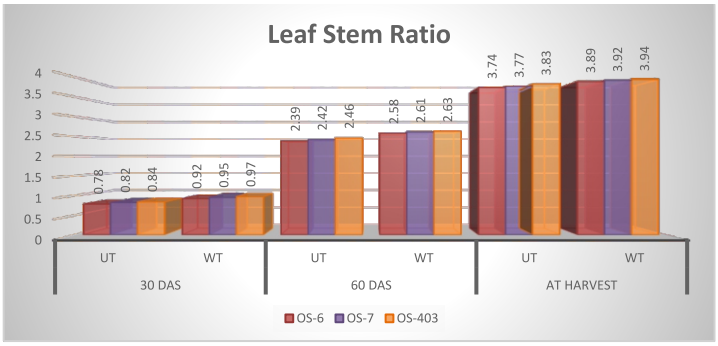

Figure 4: Leaf stem ratio at 30, 60 DAS and maturity of oat varieties in under tree and control (field without trees) condition

3.4 Leaf area and leaf area index

The leaf area index (LAI) (Figure 5) showed that higher foliage coverage per unit of land resulted in more photosynthesis by the crop. OS-403 variety shows superiority in leaf area and LAI over all other varieties.

The results showed that the leaf area index of oat varieties was found higher without trees than under *Melia dubia* at different time intervals of growth. It could be due to the tree crop competitive interaction which led to lower photosynthetic activity thereby sluggish cell division and cell elongation and consequently lower height of plants in under tree conditions as compared to open. The findings of the present study agree with the results of [15]. OS-403 variety performed better in terms of leaf area index without tree and under tree conditions at maturity revealing it as a potential genotype in intercropped conditions too. The reduction in leaf area and LAI under the agroforestry system was due to reduced availability of light under agroforestry in comparison to control.

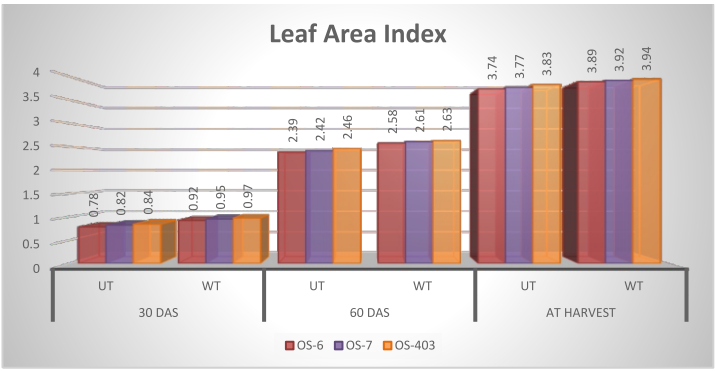

Figure 5: Leaf area index at 30, 60 DAS and maturity of oat varieties in under tree and control (field without trees) condition

3.5 Grain yield (t/ha)

(Table 1) shows that Lesser green fodder yield under trees may be due to the availability of less solar radiation and more competition for moisture and nutrients among tree and oat varieties. The yield of crops grown was influenced greatly by the amount of shade and light proportion in a day. Green fodder yield is the net resultant of its genetic makeup and the environmental condition in which the plant grows, the treatment imposed and is an important criterion for judging and comparing the efficiency of different treatments and is the decisive factor. Green fodder yield is the function of various growth and yield attributing characters like plant height, leaf stem ratio, leaf area index, dry matter accumulation, and number of effective tillers, etc. of crop plants which are reduced with the integration of trees. The present results corroborate the findings of [6]. Trees grown in an agroforestry system compete with agricultural crops for resources and result in a reduction in grain yield. During March, *Melia dubia* leaves start emerging and by this time oat crop enters into maturity. Hence, shading by leaves is the factor for the reduction in green fodder yield. Similar observations were also reported by [23].

3.6 Dry fodder yield (q/ha)

Dry fodder yield of crops is basically a product of green fodder yield after moisture reduction. The (Table 1) showed that the environment has a significant effect on dry fodder yield i.e. under tree straw yield was 5.85 t/ha and in without tree 7.77 t/ha. This might be due to the fact that the lower light intensity decreased the rates of photosynthetic activity under the trees; affected the relative growth rate, and reproductive and ripening phases of crops and thus, ultimately lead to loss of yield. These results agree with the findings of [7].

Table 1: Green fodder yield and dry fodder yield of oat varieties

Days After Sowing						
Genotype/Environment	**GREEN YIELD**			**DRY YIELD**		
	UT	WT	UT	WT	UT	WT
OS-6	28.16	35.41	31.79	5.63	7.42	6.52
OS-7	29.34	37.37	33.36	5.82	7.81	6.82
OS-403	30.31	38.16	34.24	6.12	8.08	7.10
MEAN	29.27	36.98		5.85	7.77	
C. D. at 5%	G=1.89; E=1.54; G×E= NS			G=0.36; E=0.30; G×E= NS		

3.7 Radiation

The data on light availability for oat varieties during the entire season from November 2021 to March 2022 (Table 2) showed that perennial plants have a significant impact on this factor. The measurements are taken under two conditions: under tree (UT) and without tree (WT), with their means calculated. Light intensity increases throughout the day, peaking at 2:00 p.m. under both conditions. Intensity also rises as the plants mature. For instance, at 2:00 p.m., light intensity increases from 515.5 lux (30 DAS) to 934.9 lux (maturity) in the mean values. The highest light intensity is observed in WT conditions at all times and stages. The light intensity received by the sole oat varieties was significantly higher than under the plantation of *Melia dubia*. The lower amount of light intensity recorded under *Melia dubia* might be due to the shading effect of trees in the plantation which covered the annual crops. [13] observed similar observations while working in an agri-Silvi-horticultural system.

Table 2: Light intensity absorbed by plants in open and under canopy of Melia dubia at 30, 60 DAS and maturity of crop

Days After Sowing									
Time / Environment	**30 DAS**			**60 DAS**			**At maturity**		
	UT	**WT**	**Mean**	**UT**	**WT**	**Mean**	**UT**	**WT**	**Mean**
8:00 a.m.	25.3	79.6	52.5	26.4	98.8	62.6	45.7	160.2	103.0
10:00 a.m.	45.8	340.4	193.1	61.9	370.5	216.2	88.3	561.7	325.0
12:00 p.m.	163.0	589.1	376.1	208.5	704.8	456.7	213.1	1032.8	623.0
02:00 p.m.	338.2	692.7	515.5	402.6	858.6	630.6	519.6	1350.1	934.9
04:00 p.m.	146.1	512.1	329.1	158.2	645.5	401.9	160.2	1024.3	592.3
Mean	143.7	442.8		171.5	535.6		205.4	825.8	
CD at 5%	T=4.62;E=2.92; T×E=6.53			T=9.94;E=6.28; T×E=14.06			T=16.77;E=10.61; T×E=23.72		

3.8 Growth of *Melia dubia* Cav. At the initial and harvest stages of the experiment:

At both the beginning and end of the experiment (Figure 6) showed that trees intercropped with different oat varieties exhibited a greater mean diameter at breast height (DBH) compared to trees grown without oats. Initially, the DBH for intercropped trees was 59.1 cm, increasing to 59.5 cm by the end of the experiment. In contrast, the pure stand had a DBH of 57.5 cm at the start and 57.8 cm at the end of the experiment. Similarly, tree height in intercropped conditions was 17.6 m at the start and 17.8 m at the end, while pure stand measured 17.5 m initially and 17.7 m later. Canopy spread also favored intercropped trees, which had a mean of 8.5 m compared to 8.2 m for those without oats. [5] reported that *Populus deltoides* trees in agroforestry systems with annual crops produced more timber than those grown without any crops. [24] emphasized the mutual benefits of agroforestry systems, which enhance growth through improved soil management. The results align with [21], who noted that intercropping improves root growth by increasing soil aeration and reducing compaction, leading to better overall tree growth.

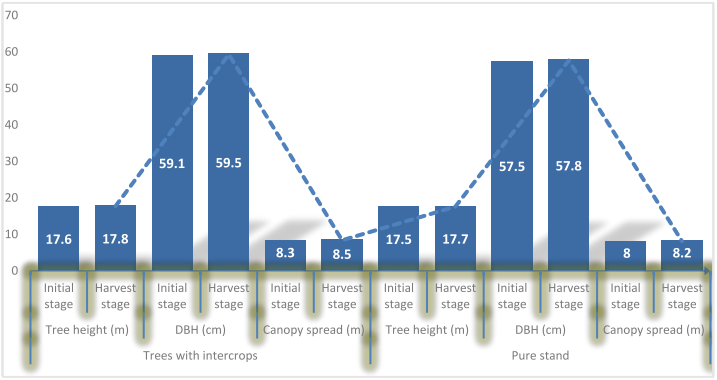

Figure 6: Tree growth parameters at initial and harvest stages of experiment in intercropped and pure stand of Melia dubia

4. Conclusion

The study shows that growing *Melia dubia* trees in the semi-arid region of Haryana as part of an agroforestry system has positive effects on different growth characteristics viz. plant height, number of tillers, leaf stem ratio, and leaf area index were found higher in open conditions as compared to under *Melia dubia*. Among all varieties, OS- 403 was recorded with maximum plant height, number of tillers, leaf stem ratio and leaf area index in both environments. OS- 6 was recorded with minimum plant height, number of tillers, leaf stem ratio and leaf area index in both environments. Among three oat varieties, OS-403 was recorded with maximum green fodder yield (34.24 t/ha) and maximum dry fodder yield (7.10 t/ha) whereas minimum green fodder (31.79) and dry fodder yield was found in OS-6. The percent reduction in green fodder yield when grown under tree plantation was recorded maximum in OS-7 (21.4) followed by OS-403 (20.5) and OS-6 (20.4), respectively. The percent reduction in dry fodder yield when grown under tree plantation was recorded maximum in OS-7 (25.4) followed by OS-403 (24.2) and OS-6 (24.1), *Melia dubia* respectively. The highest light intensity is observed in WT conditions at all times and stages. The light intensity received by the sole oat varieties was significantly higher than under the plantation of *Melia dubia*. DBH, tree height, and canopy spread of *Melia dubia* were found higher in the agroforestry system as compared to pure stand.

5.Acknowledgments

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