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Potential of *Melia dubia*-wheat based agroforestry system to cope up with climate change

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ABSTRACT

Climate change has impact on agricultural production, because it raises CO_2 levels in the atmosphere, which leads to higher temperatures. Agroforestry systems aid in climate change adaptation and mitigation by providing relatively lower temperature beneath the tree canopy. Therefore, diversified agricultural systems are needed to be identified and studied throughout the world that can help annual crops in providing better survival conditions with least effects on yield. Although food crop output in agroforestry systems is lower than in open regions, agroforestry is seen to be capable of supporting food security, soil and water conservation, land use diversification, and micronutrient adequacy and most importantly climate change mitigation. The present study showed that all the tree parameters (*i.e.,* tree DBH, tree height and canopy spread) recorded in the intercropped conditions (*Melia dubia* based agroforestry system) were found higher compared to the trees devoid of intercrops. Trees with intercrops showed more canopy spread, tree height and DBH (6.9 m, 16.3m, 56.6 m) as compared to pure stand (6.6 m, 16.2 m, 55.6 m) of *Melia dubia* trees. The canopy temperature depression (CTD) of wheat crop grown with *Melia dubia* trees was -5.58 ^{0}C whereas; -5.27 ^{0}C CTD was recorded in non-shaded conditions. Significantly higher biological yield was observed in wheat variety HD 3086 in open and intercropped conditions (134.9 q/ha and 100.5 q/ha respectively). Study revealed that *M. dubia* based agroforestry provides trees to perform better in intercropped conditions and provides favourable environment for the crop growing beneath in terms of lowering temperature and maintaining apt moisture to the crop raised beneath.

Introduction

Agroforestry is an intersection between agriculture and forestry as a promising and sustainable land use activity because of their potential to absorb atmospheric CO_2 and store it in plant biomass and soil; some agroforestry practises have attracted increased attention for their net carbon sequestration impact. As a coping mechanism against the negative effects of climate change, agroforestry offers a unique opportunity to combine the twin goals of climate change adaptation and mitigation (Yirefu *et al*., 2019). Climate change has the greatest impact on agricultural systems. Trees play an important role in reducing vulnerability, increasing farming system resilience, and protecting households from climate-related risks (Arya *et al.,* 2018). It has emerged as a promising way to improve resistance to current and

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future climate change. Agroforestry systems have a win-win situation by serving as carbon sinks while also assisting to food security, increasing farm profits, improving soil quality, and reducing deforestation (Nanda *et al*., 2021b).The number of agroforestry-related research in the Asia is rapidly increasing; India and China are hotspots for agroforestry studies with supportive policies and institutes (Shin *et al.,* 2020) that have possibly assisted in increase of forest cover share in the world by both the countries. Traditional agroforestry activities promote species diversity and serve as proof of biodiversity reserves that need additional research and development attention (Saikia *et al*., 2017). In the current climate change situation, agroforestry activities are emerging as a promising solution for mitigating climate change's negative effects. Agroforestry has a lot of potential in India. This method can be implemented on a broad hectare of land that is accessible in the form of borders, bunds and wastelands. This method allows appropriate tree species to be grown in fields. Agroforestry systems comprises different models used in various parts of the world increasing tree-crop diversification, which leads to greater carbon storage capacity than solely cultivating agricultural crops (Toppo and Raj 2018). *Melia dubia* generally known as Malabar neem is a fast-growing tree species that could help to deal with rising global temperature. *Melia dubia* tree is well adapted to various climatic zones hence, can be successfully integrated in agroforestry systems all over the country. *Melia* tree creates very suitable environmental conditions for the crop raised beneath its canopy (K. N., *et. al.* 2021). *Melia dubia* tree could be one such alternate indigenous fast growing multipurpose tree species highly suitable to agroforestry systems in India with immense potential to serve the mankind by wide range of products and environmental services (Chauhan *et al.,* 2019, Nanda *et. al,* 2019).This paper consists of findings on tree-crop (*i.e., Melia dubia*–wheat) interaction concentrating on the possibilities of agroforestry systems to combat climate change demonstrating how agroforestry programmes can easily combine mitigation and adaptation methods, providing a variety of options for ensuring food security for poor farmers while also helping to mitigate climate change.

Material and Methods

Description of the study area

The research was carried out in village Gillan Khera of district Fatehabad, Haryana, India located at 29˚50’ latitude and 75˚30’ longitude in Haryana of north-western India. The mean annual rainfall is 360-400 mm, 70-80 per cent rainfall occurs during July to September in this area. Data collection for the study was done in a 5-year-old plantation (planted during August 2013) of *Melia dubia* planted at a spacing of 3m × 3m. Five wheat varieties were raised in randomized block design taking four replications for each variety of wheat in the interspaces of the trees during *rabi* season on 15th November 2018.

Data collection

Growth studies of *Melia dubia* Cav. at initial and harvest stages of experiment

The DBH, tree height and canopy spread were recorded following the standard rules from *Melia dubia* plantation prior and after harvest of wheat 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). Height of the trees was calculated with the help of clinometer and expressed in meter. The average values of crown spread in north-south and east-west directions were calculated and expressed in meter at sowing time and after harvesting of agricultural crop (Hangarge *et al*., 2012).

Canopy temperature depression (CTD, ^{0}C):

Canopy temperature (CT) was recorded with Hand held infrared thermometer (IRT) using the model AG-42, Tele temp Corp, Fullerton. Measurements were taken between 12:00 to 14:00 (IST) on bright, cloudless days three recordings per plot at about 0.5 m from the edge of the plot and approximately 0.5 m over the canopy with an approximately 30-60^o from horizontal (Hojjat *et al*., 2012). The following formula was used to calculate Canopy temperature depression:

CTD (^{0}C) = Canopy Temperature (CT) – Ambient Temperature (AT)

Biological yield (q/ha)

After harvesting of wheat varieties sun dried weight of all plants in each net plot was recorded and calculated for biological yield of crop later converted into q/ha. Biological yield was calculated for both the environments *i.e.,* wheat varieties growing under trees in intercropping and wheat varieties growing under trees devoid of wheat varieties. 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.

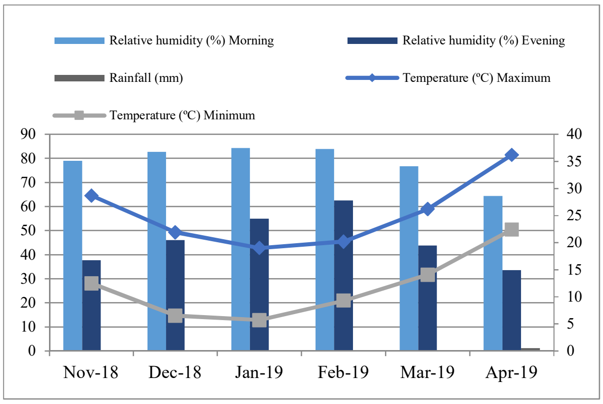

Figure 1: Monthly weather data of site of experiment from November 2018 to April 2019

Fresh and dry matter accumulation at 30, 60, 90, 120 DAS and at maturity

Fresh samples of plants of 0.5 m^2 from each replication for each variety were taken and weighed immediately after cutting them from base of the ground at 30, 60, 90, 120 DAS and at maturity. Dry weight from same samples was weighed for dry matter accumulation. Samples were put in open for sun drying and then were put in oven at 60 ^{0}C till a stable weight was obtained.

Results and Discussion

Tree parameters

At both the beginning and end of the experiment, the mean diameter at breast height was observed to be greater in trees intercropped with different wheat varieties than in trees without wheat varieties as an intercrop. In intercropped conditions, the mean DBH measured at the start of the experiment (November 2018) was 56.2 cm and increased to 56.6 cm at the end of the experiment (April 2019). Trees growing without wheat varieties underneath them, on the other hand, had a mean DBH of 55.3 cm at the start and 55.6 cm at the end. As a result of the data (Table 1) it appears that trees grown with wheat as an intercrop have a higher DBH increase. At the beginning and end of the trial, the mean tree height (Table 1) found in trees standing with wheat varieties was 16.1 m and 16.3 m, respectively. However, the average height of trees growing without wheat varieties was 16.1 m before wheat varieties were planted (November 2018) and 16.2 m after wheat varieties were harvested (April 2019). Chaudhry *et al.* (2003) in their study found that *Populus deltoides* stand raised as agroforestry trees (having annual crops beneath) yielded more timber than the trees growing alone without any crops. The mean canopy spread (6.9 m) observed in trees with intercropped conditions was greater than that of standing trees without wheat varieties as intercrop, *i.e.*, 6.6 m in the end of season, according to the data provided in Table 1. As a result, evidence shows that intercropped environments result in a greater increase in canopy growth. According to Singh and Oraon (2017), agroforestry systems have a dynamic relationship between tree and crop components that benefits both the systems. The mean of DBH, tree height, and canopy spread of *Melia dubia* trees, as seen in, shows that DBH, tree height, and canopy spread were all higher in intercropped conditions than in pure *Melia dubia* stands. These findings may be attributed to soil management techniques used in intercropping situations, which resulted in improved root growing conditions through increasing aeration and decreasing soil compactness. Similar remarks have been given by Nandal and Kumar (2010).

Canopy temperature differences in shaded and non-shaded environment

The data of Canopy temperature depression (CTD) revealed more CTD under shaded conditions as compared to open conditions as can be seen in (Table 2). Among both the environment highest CTD was observed in WH 1105 followed by DBW 88, WH 711, HD 3086 and HD 2967 in shaded conditions. The decreased values of Canopy temperature depression (CTD) under open conditions might be due to higher rate of transpiration than shaded conditions that leads to water deficit and cause warmer canopy in open conditions. Similar results were also observed by Roohi *et al.*, 2015 and Chaudhari *et al.*, 2017 in wheat genotypes.

Table 1: Tree growth parameters at initial and harvest stage of experiment in intercropped and pure stand of *Melia dubia*

	Trees with intercrops						Tree without intercrops					
	DBH (cm)		Tree height (m)		Canopy spread (m)		DBH (cm)		Tree height (m)		Canopy spread (m)	
SN	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
1.	45.8	45.9	13.8	13.9	5.6	5.7	70.6	70.8	13.9	14.1	8.5	8.8
2.	63.4	63.6	15.3	15.6	7.3	7.6	70.5	70.6	18.9	19.0	5.0	5.1
3.	70.8	70.9	18.5	18.6	8.2	8.4	61.1	61.2	16.9	17.0	4.5	4.7
4.	60.2	60.8	18.3	18.5	6.1	6.4	70.3	70.8	16.6	16.7	6.2	6.4
5.	70.3	70.9	15.1	15.4	7.4	7.8	44.4	44.6	14.9	14.9	5.8	6.0
6.	45.4	45.7	14.2	14.3	6.4	6.5	58.3	58.4	18.6	18.9	7.4	7.7
7.	58.1	59.3	16.2	16.3	6.0	6.3	32.5	32.8	18.2	18.2	6.0	6.3
8.	34.8	34.9	14.0	14.1	5.1	5.3	40.8	41.0	15.5	15.6	7.8	7.9
9.	42.5	42.8	17.2	17.5	5.8	6.0	59.2	60.2	14.0	14.1	7.0	7.1
10	70.8	70.9	18.6	18.9	9.0	9.2	44.9	44.9	13.5	13.7	5.7	5.8
Mean	56.2	56.6	16.1	16.3	6.7	6.9	55.3	55.6	16.1	16.2	6.4	6.6

Other physiological parameters such as photosynthetic rate, stomatal conductance and transpiration rate, decreased significantly in shaded conditions as compared to open conditions. In both environments, high CTD values were found in the intercropped condition. As compared to open conditions, the temperature under the canopy of trees in an agroforestry environment is significantly lower. As a result, for a planet dealing with climate change, agroforestry can be a viable alternative for growing crops that can provide relief to plants as intercrops from high temperatures. However, since the agroforestry environment is a dynamic ecosystem, smart crop choice will also be an essential criterion for obtaining optimal yields, whether visible or intangible. High canopy temperature depression (CTD) or low CT, according to Reynolds (1994), can indicate a high demand for photosynthates during the rapidly grain filling stage in resistant lines. Agroforestry has been suggested as a possible solution for reducing climate change vulnerability. It's a resource management scheme that incorporates trees on a farm that's dynamic and ecologically sound. On the field, trees provide development and security.

Biological yield

The biological yield of a crop determines its productivity in large part. The biological yield (Table 3) was significantly influenced by environment *i.e.,* higher biological yield in without tree (121.9 q/ha) was observed in comparison to under tree plantation (89.5 q/ha). The interaction effect between crop environment and variety were also found significant. According to Gill *et al.* (2009), the biological yield of wheat declined under tree plantation. HD 3086 (117.7 q/ha) had the highest biological yield of wheat varieties. However, wheat variety WH 711 (91.8 q/ha) had the lowest biological yield. Low biological yield could be attributed to competition for growth resources, especially sunlight, between *Melia dubia* trees and wheat varieties. Similar reasons have been stated by Mishra *et al.* (2010) and Kumar *et al.* (2013) in their research. According to Chauhan *et al.* (2015) wheat and barley yields were lower under the poplar canopy than in the open however, they stated that the poplar-based agroforestry system with conventional wheat crop offers a better potential for farm diversification and income than a single cropping system. When compared to single cropping, Bisht *et al.* (2017) found a decline in the biological yield of wheat growing under poplar. They discovered that sunlight, moisture, and nutrients were the most important major constraints in intercropping wheat crop growth and yield (Nanda *et. al*., 2021a).

Fresh and dry matter accumulation at 30, 60, 90,120 DAS and at maturity

The accumulation of fresh and dry matter of plant is an important parameter which influences the production of yield attributes and yield of plant by adequate transfer of assimilates to the sink. Dadhwal and Narayan (1984) reported more DMA of in wheat growing without tree (*i.e.,* in open) in comparison to under tree conditions because translocation of photosynthates was happening to both *i.e.,* trees as well as wheat varieties. Roots of trees are deep rooted as compared to wheat so uptake of nutrients and water were more by trees as compared to open conditions.

Table 2: Effect of environment on canopy temperature depression at flag leaf in wheat varieties

Canopy temperature depression (CTD, ^{0}C)			
Variety	**Under tree**	**Without tree**	**Mean**
WH 1105	-6.07	-5.37	-5.72
WH 711	-5.70	-5.63	-5.67
DBW 88	-5.87	-5.60	-5.73
HD 3086	-5.13	-4.80	-4.97
HD 2967	-5.13	-4.97	-5.05
Mean	-5.58	-5.27	
C. D. at 5%	Variety =0.29; Environment =0.18; Variety × Environment = NS		

Table 3: Biological yield (q/ha) of wheat varieties in intercropped and pure stand of *Melia dubia.*

Variety	**Under tree**	**Without tree**	**Mean**
WH 1105	95.2	129.3	112.2
WH 711	77.3	106.2	91.8
DBW 88	80.4	109.1	94.8
HD 3086	100.5	134.9	117.7
HD 2967	94.2	130.1	112.2
Mean	89.5	121.9	
C. D. at 5%	Variety=1.68; Environment=1.07; Variety X Environment=2.38		

The effect of environment on wheat varieties was well pronounced on growth attributes such as plant fresh and dry matter accumulation. The fresh and dry matter accumulation in different wheat varieties differed significantly among plantation and in control (without tree) from 30 DAS to maturity (Fig. 2 and 3). At 120 DAS and at harvest significantly higher fresh matter accumulation was recorded in HD 3086 which is at par with HD 2967. However minimum fresh matter accumulation recorded in WH 711 in all the growth stages. At harvest significantly higher dry matter accumulation was recorded in HD 3086 which is at par with WH 1105 and HD 2967 in both the environment. However, significantly lesser dry matter accumulation was observed in WH 711 in under tree and open conditions at maturity. The dry matter accumulation of wheat varieties was recorded higher in without tree condition than the varieties growing under trees. Reduced amount of dry matter accumulation may be ascribed to competition between tree and wheat varieties for light, moisture and nutrients in *Melia dubia* based agroforestry system. Similar results were obtained by Alebachew *et al.* (2015). Result of the present study support the findings of Bargali *et al.* (2009), Datta and Singh (2007), Bhati *et al.* (2008), Osman *et al.* (1998) and Evensen *et al.* (1995). Wassinck (1954) revealed that photosynthetic efficiency of crops increased because of presence of more light intensity in control that resulted in better growth performance of crop. Crop yield was reduced mostly due to the decrease in light intensity underneath the trees; this could be mitigated by increasing plantation width and proper training and pruning of trees on a regular basis. Agri-silvicultural systems based on poplars produce a lot of litter, which increases the amount of organic matter in the soil Arya and Toky (2017). Similarly, *Melia dubia* is a deciduous tree, it contributes a significant amount of organic matter to the soil. If handled properly, agroforestry systems can help to not only deal with environmental problems, but also increase their profits by diversifying their sources of income. Since the majority of India's arable land is cultivated, agroforestry on agricultural fields would have a significant proportion of the ability to store carbon by afforestation. The overall carbon storage capacity of an agroforestry system varies from region to region and is determined by the growth and function of the individual tree species (Basu 2014).

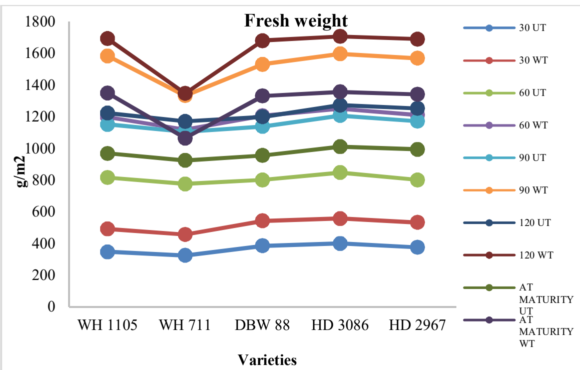

Figure 2: Fresh matter accumulation (g/m^2) at 30, 60, 90, 120 days and at maturity of wheat varieties

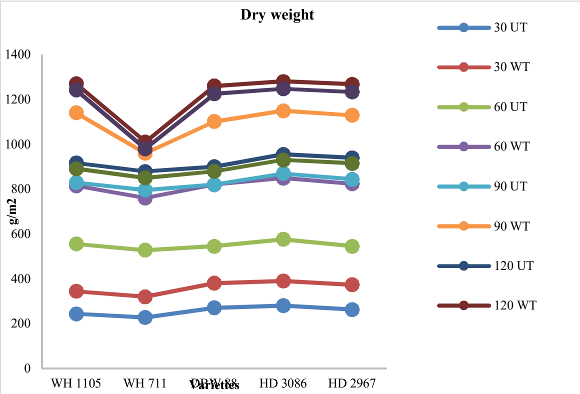

Figure 3: Dry matter accumulation (g/m^2) at 30, 60, 90, 120 days and at maturity of wheat varieties

of *Melia dubia*. This demonstrates that trees have better growth in agroforestry environment. Planting trees on farmland expands the tree canopy outside of forests and eventually adding to total tree cover of the country. Also trees in *Melia dubia* based agroforestry system provides cooler environment to the wheat crops growing under them. The research discovered a number of beneficial environmental properties of trees in relation to wheat production. *Melia dubia* can be suggested as a possible tree in an agroforestry system in provinces with similar climatic conditions to cope with shifting climatic conditions and to increase farmer profits, according to the current report.

Conclusion

In order to slow the rise in temperature, immediate action is needed in the face of climate change. Trees, forests and agriculture are key to reducing carbon emissions and combat climate change. Farmers can better prepare for climatic effects by planting the appropriate tree species in combination with appropriate crop species. In the present study five wheat varieties were raised under *Melia dubia* plantation. Various growth parameters studied such as DBH, tree height, and canopy spread were found higher in agroforestry system (wheat varieties growing under trees) compared to a pure stand (trees not having any annual crop growing beneath)

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Conflict of interest

The authors declare that they have no conflict of interest.

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