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Performance of *Melia dubia* Cav. and yield of under storey crops in Punjab, India

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ABSTRACT

The study was carried out to determine growth performance of *M. dubia* and yield performance of underlying wheat and maize in Punjab. Experimental plots of each acre in Randomized Block Design (RBD) pattern with 4x5 m, 5x5 m and 4x6 m spacing were established in Handesra District Mohali (SAS Nagar) and Hukran (District Hoshiarpur). 10 quadrates of 1x1 m were laid in each plot to study yield of under story crops 1 to 4 years. The crop falling under each quadrate was harvested and weighed for total biomass after drying it and then threshed to get grains. It is clear from the result that irrespective of age growth was higher in 4X6 meter spacing. The findings of the study revealed that *M. dubia* is a suitable species for agroforestry system in Punjab. It can gain up to 14 m height with an average girth of 65 cm in 4 years. More variation was seen between grain yields of maize and age of plants. Results showed that except in some plots, yield of maize crop under *M. dubia* was higher in District Hoshiarpur. Overall, the interaction of *M. dubia* species with maize and wheat crop was found suitable without any adverse effect on yield. It is recommended to provide proper guidance and extension tools to convince farmers to adopt and raise *M. dubia* with wheat and maize crops.

Key Words:

Agroforestry, Growth, Performance, Plantation, Tree-crop interaction, Yield

INTRODUCTION

Melia dubia Cav. commonly known as Burma Neem and its trade name in India is Malabar Neem. In India, it is found in Sikkim, Himalaya, North Bengal, Upper Assam, hills of Orissa, Deccan and Western Ghats, Gujarat at altitudes of 1500 to 1800 m (Saravanan et al. 2013; Chauhan et al. 2018; Thakur et al. 2019). It occurs in moist localities and tropical forests. It yields useful timber for furniture, agricultural implements and house construction, plywood and pulp wood, owing to its high pulp recovery and exceptional fibre strength as compared other raw material (Parthiban et al. 2009; Sinha et al. 2019). Apart from ornamental purposes it also makes a good avenue and shading tree, if pollarding is done for shade purpose. Its fruit pulp has been reported as energy rich feed source (Sukhadiya et al. 2019; 2020). It grows rapidly and hence is a favoured species in agroforestry. Many *M. dubia* based agroforestry systems have been investigated for its bio-physical and economic feasibility with pulse, vegetable crops and medicinal and aromatic plants (Jilariya et al. 2017; Mohanty et al. 2017; Bhusara et al. 2018a & b; Thakur et al. 2018; Mohanty et al. 2019; Thakur et al. 2019; Jilariya et al., 2019). It has been reported with no or ephemeral allelopathic effect on under-storey crops (Kumar et al. 2017; Thakur et al. 2017a & b; Parmar et al. 2019). In Punjab locally called as "Burma Drek". It is a fairly large, deciduous and fast growing tree and widely grown in agroforestry in plains of northern India. The tree has a straight, cylindrical long bole up to a height of 20 m. It can gain height up to 14 m with an average girth of 65 cm in 4 years age of plant. The wood of this species is useful for packing cases, cigar boxes, ceiling planks, building purposes, agricultural implements, pencils, match boxes *etc.*

Tree-Crop interaction is a common phenomenon in agroforestry where trees are grown in association with crops. In agroforestry, tree and agricultural crops are combined together and they compete with each other for resources such as light, water and nutrients (Verma et al. 2010; Gupta et al. 2012; Thakur et al. 2014; Kaushal et al. 2017). *Melia dubia* besides providing timber also produce a good quantity of fuel wood under a regular and proper canopy management. Proper guidance to farmers to adopt agroforestry practices through different extension tools can also be helpful to raise the forestry species like *M. dubia* on their farmland under agroforestry without affecting under-storey crops. This study was carried out to determine growth performance of *M. dubia* and yield performance of underlying wheat and maize as these crops are grown by most of the farmers in Punjab.

MATERIALS AND METHODS

Study area

Punjab state is located between 28.31° to 32.32°N latitude and 75.55° to 76.56°E longitude towards North-Western part of the country. The temperature inn winters, it varies from 1°C to 25°C and 26°C to 45°C in summer. The soil in the state is lightly sandy having different profile in different regions. The status of nutrient specially N, P and K also varied from place to place. Being an agrarian state, a large part of the population lives in the rural area. Punjab is one of the most fertile regions in the country. The total geographical area is 5036200 ha, of which 85% is under cultivation. Net sown area is 4264000 ha. 94% area is irrigated and crop intensity is 183%. The region is ideal for wheat growing, rice, sugarcane, fruits and vegetables are also grown in some parts of the state. The main agricultural crops are wheat, rice, maize, cotton, sugarcane, potato, oil seeds and pulses.

In Punjab, the percentage of marginal, small, medium and large farmers in the state is 15%, 20%, 35% and 30%, respectively (Negi et al. 2009). Under planting patterns, it has been revealed that 50% farmers have scattered trees on their farm land, 20% have block plantation while 30% farmers have adopted boundary plantation on their fields. Status of species under agroforestry practices shown as Eucalyptus (25%), Poplar (*Populus deltoides*) (20%), Drek and Bakain (*Meliaa zedarach*) (20%), Shisham (*Dalbergia sisso*) (10%), Khair (*Acacia catechu*) and Kikar (*Acacia nilotica*) (10%), Neem (*Azadirachta indica*) (5%) and other species (10%).

Methodology

An extensive survey was done in Mohali and Hoshiarpur Districts of Punjab. Phenology study of 1 to 4 years old plants of *M. dubia* in block pattern was done during the survey. Farmers were motivated to plant seedlings on their farms. The parameters of phenological study were taken in view as identification of species and its morphological characters, height and girth measurements. The yield of wheat and maize crops were also determined with reference to the sites under different spacing.

Three experimental plots of one acre each in randomized block design (RBD) with plot I: 4x5 m, plot II: 5x5 m and plot III: 4x6 m spacing was established in Handesra District Mohali (SAS Nagar) and Hukran (District Hoshiarpur) of Punjab.

In each acre plots of 4x5 m, 5x5 m and 4x6 m spacing height and girth was measured by sampling method twice a year *i.e.* in summer and winter from 1 to 4 years. In first and second year of plantation, the height and the girth of the plants was measured with the help of measuring tape. From 3rd year onwards, Ravi Altimeter was used for height measurement.

The data was also collected on intercrops wheat and maize regularly from 1 to 4 years. 10 quadrates of 1 x 1 m in the crops of wheat and maize were laid in each plot to study yield of under story crops in every year. The crop falling under each quadrate was harvested and weighed for total biomass after drying it and then threshed to get grains. After weighing biomass and grains, total sample as averaged and yield in kg m^{-2} was calculated.

RESULTS AND DISCUSSION

Growth of M. dubia

Growth data *i.e* height (m) and girth (cm)of *M. dubia* at 4x5 m, 5x5 m and 4x6 m spacing 1 to 4 years of age at Handesra and Hukran are given in table 1. In Handesra, district Mohali, in 1st year maximum height (3.00 m) was in 4x6 m spacing and maximum girth (16.33 cm) was recorded in 4x5 m spacing. In 2nd year maximum height (7.00 m) in 4x6 m spacing while maximum girth (29.37 cm) was recorded in 4x5 m spacing. In 3rd year, maximum height (11.30 m) in 5x5 m spacing while maximum girth (40.32 cm) was in 4X6 m spacing. Similarly, in 4th year maximum height (13.00 m) and girth (55.50 cm) in 4X6 m spacing (Table 1). In Hukran, district Hoshiarpur, in 1st year maximum height (3.00 m) was in 4x6 m spacing and maximum girth (15.00 cm) was recorded in 4x6 m spacing. In 2nd year maximum height (7.00 m) in 4x6 m spacing while maximum girth (26.50 cm) was recorded in 5x5 m spacing. In 3rd year, maximum height (13.0 m) in 4x6 m spacing while maximum girth (32.00 cm) was in 4X6 m spacing. Similarly, in 4th year maximum height (14.22 m) and girth (65.80 cm) was found in 4X6 m spacing (Table 1). The findings from the study revealed that *M. dubia* is a suitable species under agroforestry system in Punjab. It can gain upto 14 m with an average girth of 65 cm in 4 years.

Wheat (*Triticum aestivum* L.)

In Handesra grain yield of wheat in 4x5m spacing (Plot I), 5x5m spacing (Plot II) and 4x6m spacing of 1 to 4 years are shown in table 2. Results indicated that in Handesra, District Mohali; under all age tree plantation (1, 2, 3 and 4 year old plantation), grain yield was maximum under 4X6 m spacing. The highest yield was 52.5 q ha^{-1} in 2nd year at 4 x 6 m spacing. Likewise, in Hukran, District Hoshiarpur wheat yield under all age tree plantations (1, 2, 3 and 4 year old), was maximum under 4x6 m spacing. The maximum yield (56.0 q ha^{-1}) recorded in 4 x 6 m spacing in first year. A difference was seen between grain yields of wheat in Handsera, District Mohali and Hukran, Hoshiarpur District in Punjab.

Maize (*Zea mays* L.)

Maize grain yield in Handesra, District Mohali under all age tree plantation (1, 2, 3 and 4 year old plantation) was also maximum under 4X6 m wider spacing. The highest yield was 47.0 q ha^{-1} in 1st year at 5 x5 m and 4 x 6 m spacing (Table 2). Maize grain yield in Hukran, District Hoshiarpur under three age tree plantation (1, 2, and 3 year old plantation), was maximum in 4X6 m wider spacing while in 4th year, maximum grain yield was received from 4X5 m spacing . The highest yield was 48.0 q ha^{-1} in 1st year 4 x 6 m spacing (Table 2).

Table 1. Growth performance of *M. dubia* at Handesra (Mohali) and Hukran (Hoshiarpur) Punjab

Age of plantation (years)	Growth	Handesra (District Mohali)			Hukran (District Hoshiarpur)		
		Spacing (m)			Spacing (m)		
		4X5 (plot-I)	5X5 (plot-II)	4X6 (plot-III)	4X5 (plot-I)	5X5 (plot-II)	4X6 (plot-III)
1 year old	Ht (m)	2.36±0.05	2.50±0.07	3.00±0.25	2.50±0.25	2.90±0.05	3.00±0.25
	Girth (cm)	14.66±1.9	14.03±1.8	16.33±0.05	13.00±0.5	14.00±2.0	15.00±0.25
2 year old	Ht (m)	5.96±0.50	6.03±0.50	7.00±0.50	6.00±0.50	6.50±0.35	7.00±0.97
	Girth (cm)	29.37±2.0	20.12±0.5	22.00±0.11	20.50±1.0	26.50±1.0	25.50±0.50
3 year old	Ht (m)	11.27±0.7	11.30±0.7	11.00±0.55	12.00±0.3	12.00±0.5	13.00±1.05
	Girth (cm)	40.10±3.0	39.93±0.9	40.32±3.05	29.30±1.0	30.50±1.9	32.00±2.13
4 year old	Ht (m)	11.39±1.2	12.00±1.0	13.00±1.05	12.50±1.1	13.00±1.0	14.22±1.25
	Girth (cm)	50.57±1.0	52.57±1.2	55.50±2.01	44.33±2.0	45.50±2.2	65.80±3.32

Table 2. Yield of Wheat and Maize under *M. dubia* atHandesra (Mohali) and Hukran (Hoshiarpur) of Punjab.

Age of plantation	spacing	Handesra (District Mohali)		Hukran (District Hoshiarpur)	
		Crop yield (Q ha^{-1})		Crop yield (Q ha^{-1})	
		Wheat	Maize	Wheat	Maize
1 year old	4X5	50.3	46.0	52.0	47.0
	5X5	50.0	47.0	55.0	47.5
	4X6	52.0	47.0	56.0	48.0
2 year old	4X5	45.0	43.0	49.0	42.0
	5X5	50.5	43.0	53.0	43.0
	4X6	52.5	45.0	55.0	45.0
3 year old	4X5	35.3	40.0	49.0	41.0
	5X5	36.0	41.0	52.0	40.0
	4X6	36.0	42.0	54.5	42.0
4 year old	4X5	22.25	35.0	25.0	40.0
	5X5	25.0	36.0	30.0	38.0
	4X6	26.0	37.0	32.0	39.0

DISCUSSION

Tree-Crop interaction is an important aspect in agroforestry where trees are grown in association with crops. The positive (complementary) and negative (competitive) effects of tree in agroforestry systems have been realized (Verma et al. 2010; Thakur et al. 2011, 2014; Koul and Panwar 2012; Yadav et al. 2014; Suvera et al., 2015; Kumar et al. 2016; Jilariya et al. 2017; Thakur et al. 2018; Thakur et al. 2019). Competition between trees and crops for the same limiting growth resources is most obvious when they are grown in close proximity. However, the extent of below ground competition is often not apparent. In agroforestry system, competition between tree and crop is usually a significant factor, which has a negative impact on extension of agroforestry.

Tewari (1995) described different agri-silviculture systems where both boundary and block plantation of forestry tree species like *Populus deltoides*, *Eucalyptus* spp., *Dalbergia sissooo, Leucaena leucocephala* and *M. azedarach*, *etc.* have been used as tree component. The study is synchronized with the study done by Warrier et al. (2012) conducted on comparative growth performance of *M. dubia*, *Gmelina arborea*, *Anthocephalus kadamba* and *Acacia mangium* where the growth performance of *M. dubia* was found on top having a girth of 75.00 cm with mean annual increment of 25.00 cm per year and growth rate 2.08 cm per month in planted in block with 5x5 m spacing. Dhiman (2012) observed during such a study conducted in Punjab, Haryana, Uttar Pradesh and Uttarakhand that under agroforestry stratified area wheat was main crop with 51.67 percent followed by sugarcane, sorghum, barseem, maize, jowar, bajra, paddy, *etc* under poplar based agroforestry. He also revealed that 58.38 percent poplar was in compact block plantation while 41.62 percent was boundary plantation. Singh et al. (2013) conducted a study to find out the performance of a new variety of wheat (PBW-550) in relation to irrigation regimes in poplar – wheat agroforestry system. They noticed that under the plantation of *Populus deltoides* at spacing of 4x5 m with 4 regimes of irrigation, the yield in second year get reduced under the intercropping as compare to pure crop. Verma et al. 2013) conducted a study on six poplar clones namely PL-1, PL-2, PL-3, PL-4, PL-5 and SWL-22 under two environments *i.e.* pure poplar plantation and poplar with wheat and mung. The results revealed that all parameters of poplar clones like DBH (Diameter at Breast Height), height and crown spread were better under agroforestry system and clone SWL-22 was best under both environments. Verma and Rana (2014) undertaken investigation on performance of tree and crop of paddy and wheat under *Eucalyptus tereticornis* based agri-silviculture system on farmers land of Amirganj block of Faizabad district and found that paddy yield was 14.7% to 29.7% less under tree canopy while wheat grain yield was 25.4% to 34.6% lower that open cultivation of crops.

A *Jatropha curcus* based study was conducted for growth analysis and yield of wheat in Tarai area of North West India under the pruning of *J. curcus* at different heights i. e. 50 cm, 100 cm and 150 cm. Resultantly, it was found that pruning is essential for improving growth and yield of wheat under *J. curcus* based agri-silviculture agroforestry system (Yadav et al. 2015). A study conducted by Dhiman and Gandhi (2015) on *P. deltoides* and *Zea mays* agri-silvicultural agroforestry system indicated that age of poplar trees show significant influence on yield of *Z. mays* cobs and fodder. Tree height and diameter increment in 14 month old plantation was significantly higher than the plantation of different age. Singh et al. (2016) conducted a study on performance of promising wheat genotypes and sowing time for cultivation under *M. dubia* (*M. composita*) based agri-silviculture agroforestry system and found that wheat grain yield was significantly higher in open conditions than 3 year old block plantation of *M. dubia* and there was reduction of 21.4 percent in average wheat grain yield under *M. dubia* plantation. Rao et al.(2016) explained growth performance and yield of wheat and paddy intercropped with *D. sissoo* and revealed that wheat variety NW-1067 and paddy variety Narendra USAR-2 were better for cultivation under *D. sissoo* based agri-silviculture agroforestry system in salt affected soils.

The study is also supported by the same line the work of Singh et al. (2016) in Haridwar district of Uttarakhand and SAS Nagar district of Punjab where they found that height and color diameter at initial stage of *M. composita* (*M. dubia*) and *Emblica officinalis* was promising at both sites without hampering the growth of under storey agricultural crops. Dhillon et al. (2017) studied the spacing effects under 8 year old poplar based agroforestry where rotation of cow pea – wheat and soghum – barseem was followed under the block plantation spacing 5x4 m, 10x10 m and 18x2 m and found that growth and yield of agricultural crops decreases significantly with decrease in poplar spacing and the reduction was more severe in kharif crops. The rate of decrease in yield of sorghum fodder and wheat was more under 5x4 m spacing.

CONCLUSION

The study reveals that *M. dubia* is a suitable species for agroforestry system in Punjab. It can gain upto 14 m with an average girth of 65 cm in 4 years. Overall, a wider spacing has created a positive impact on trees growth. Under an agroforestry system such as agrisilviculture, the interaction of this species with maize and wheat crop is found suitable without making any adverse effect which are generally grown in Punjab. Due to its applicability in agroforestry, the study recommends a proper guidance and extension tools towards farmers to adopt and raise forestry species like *M. dubia* with wheat and maize crops in their fields.

REFERENCES

Bhusara JB, Dobriyal MJ, Thakur NS, Sondarva RL and Prajapati DH. 2018a. Growth and yield performance of green gram under *Melia composite* plantations. Journal of Pharmacognosy and Phytochemistry, 7(3): 1490-1494.

Bhusara JB, Dobriyal MJ, Thakur NS, Gunaga RP and Tandel MB. 2018b. Performance of okra (*Abelmoschus esculentus* L. Moench) under different spatial arrangements of *Melia composita* based agroforestry system. International Journal of Current Microbiology and Applied Sciences, 7(5): 3533-3542.

Chauhan RS, Jadeja DB, Thakur NS, Jha SK, and Sankanur MS. 2018. Selection of Candidate Plus Trees (CPTs) of Malabar Neem (*Melia dubia* Cav.) for Enhancement of Farm Productivity in South Gujarat. International Journal of Current Microbiology and Applied Sciences, 7(05): 3582-3592.

Dhiman RC. 2012. Diagnosis of intercrops in poplar based agroforestry. Indian Forester 138(7): 600 – 609.

Dhiman RC. and Gandhi JN. 2015. Cultivation of high value crop sweet corn (*Zea mays* Linn.) in poplar based agroforestry. Indian J. Agroforestry 17 (2): 70 -75.

Dillon RS, Beniwal RS, Bangarwa KS, Bharadwaj KK, Handa AK, Kumari S, Chavan SB, Rizvi RH, Sirohi C. and Sheokhand RN. 2017. Effect of spacing on crop yield and soil nutrient status under poplar based Agroforestry system in semi-arid ecosystem. Indian J. Agroforestry 19 (1): 42-47.

Gupta B, Thakur NS and Bandana Chib. 2012. Survival and growth of exotic grasses under plantations of *Eucalyptus tereticornis* in North West Himalaya. Indian Journal of Forestry, 35(2): 181-186.

Jilariya DJ, Thakur NS, Singh N. and Gunaga RP. 2019. Economics of cultivation of *Melia dubia* Cav.–*Aloe vera*L. silvi-medicinal model. Indian Journal of Agroforestry 21(2): 35-40.

Jilariya DJ, Thakur NS. And Gunaga RP. 2017. Quantitative and qualitative attributes of *Aloe vera* Linn. Grown under *Melia composite* Willd. and sole cropping systems. Indian Journal of Ecology, 44(5): 451-455.

Kaushal R., Kumar Ambrish, Alam NM., Mandal D., Jayaprakash J., Tomar JMS., Patra S., Gupta AK., Mehta H., Panwar P., Chaturvedi OP., Mishra PK. 2017. Effect of different canopy management practices on rainfall partitioning in *Morus alba*, Ecological Engineering. 102: 374-380.

Koul DN, Panwar P. 2012. Opting different land use for carbon buildup in soils and their bioeconomics in humid subtropics of West Bengal, India. Annals of Forest Research 55 (2): 253-264

Kumar D, Thakur NS and Gunaga RP. 2017. Effects of leaf aqueous extract and leaf litter of *Melia composita*Willd. on black gram [*Vigna mungo* (L.) Hepper]. Allelopathy Journal, 41(1): 127-140.

Kumar M., Thakur NS. And Hegde HT. 2016. Fresh herb, essential oil yield and net returns from *Ocimum*s pp. grown under teak (*Tectona grandis* L.f.) based silvi-medicinal systems in south Gujarat, India. Indian Journal of Ecology, 43 (1): 306-311.

Mohanty S, Thakur NS, Gunaga RP and Gajbhiye N. 2019. Influence of *Meliadubia* Cav. Spatial Geometries on Growth, Herbage Yield and Essential Oil Constituents of *Cymbopogon martinii* (Roxb.) Wats. Journal of Essential Oil Bearing Plants, 22(3): 630-648.

Mohanty S., Thakur NS. And Gunaga RP,Dobriyal MJ and Desai BS. 2017. Value addition in *Cymbopogon* spp. to enhance the financial flows from *Cymbopogon* spp.-*Melia dubia* Cav. based silvimedicinal and sole cropping systems. Indian Journal of Ecology, 44(6):812-816.

Negi SS, Bisht NS, Rawat A, Singh VRR, Kishan Kumar VS, Singh HP, Singh C, Kanswal BD, Ansari MV, Kumar K and Bisht I. 2009. Farm Forestry Extension its marketing and economic linkages. A project report, FRI, Dehradun. 1-161.

Parmar AG, Thakur NS and Gunaga RP. 2019. *Melia dubia* Cav. leaf litter allelochemicals have ephemeral allelopathic proclivity. Agroforestry Systems, 93(4):1347-1360.

Parthiban KT, Bharathi AKR, Seenivasan K, Kamala and Rao MG. 2009. Integrating *Melia dubia* in agroforestry farms as an alternate pulpwood species, APA News, 34: 3- 4.

Rao OP, Sirohi C and Verma SK. 2016. Growth and yield attributes of wheat and paddy intercropped under *Dalbergia sisso o*Roxb. Based agri-silvicultural system on partially improved salt affected soil in Faizabad district. Indian Forester 142 (5): 481 – 486.

Saravanan V, Parthiban KT, Kumar P, Marimuthu P. 2013 Wood characterization studies on *Melia dubia* Cav for pulp and paper industry at different age gradation. Res J Recent Sci2: 183-188.

Singh A. Singh RP and Kaur H. 2013.Response of wheat to different irrigation regims given under Poplar (*Populus deltoides* Bart. Ex. Marsh) based agroforestry system. Indian Forester139(1): 75 – 77.

Singh R, Kaur N, and Gill RIS. 2016. Performance of promising wheat genotypes and sowing time for cultivation under Burma dek (*Melia composita* L.) based agri-silviculture system in Punjab. Indian J. Agroforestry 18 (2): 95 -101.

Singh R, Singh C. and Gulati A. 2016.Initial growth performance of *Melia composita* Willd. and *Emblica officinalis* Gartn based agri-silvi-medicinal Agroforestry in degraded land. Indian Forester 142(3): 277-282.

Singh R, Singh C, Gulati A, and Kujur S. 2016. Current status of poplar based agroforestry for economic development. Indian Forester 142 (5): 487 – 492.

Sinha SK, Chaudhari PA, Thakur NS, Jha SK, Patel DP and Dhaka RK. 2019. *Melia dubia* Cav. wood properties vary with age and influence the pulp and paper quality. International Wood Products Journal, 10(4): 139-148.

Sukhadiya ML, Thakur NS, Gunaga RP, Patel VR, Bhuva DC and Singh S. 2019. *Melia dubia* Cav. drupe pulp: a new alternate livestock feed resource. Range Management and Agroforestry, 40(2): 299-305.

Sukhadiya ML, Thakur NS, Patel VR, Gunaga RP, Kharadi, VB, Tyagi KK and Singh S. 2020. Provenance variations in proximate principles, mineral matter, total phenols and phytochemicals of *Melia dubia* drupes: an unexplored alternate livestock feed stock. Journal of Forestry Research .doi:10.1007/s11676-019-01080-y.

Suvera A H., Thakur NS. And Jha SK. 2015. Herbage and essential oil yield of *ocimum* spp. intercropped under *Pongamia pinnata* based silvi-medicinal system in Gujarat, India. The Bioscan, 10(1): 81-85.

Tewari DN.1995. Agroforestry systems. [In: *AGROFORESTRY for Increased Productivity, Sustainability and Poverty Alleviation*. Published by R. P. Singh for International Book Distributors 15/2-B, Rajpur Road, Dehradun]: 1-799.

Thakur NS, Kumar D, Gunaga RP and Singh S. 2017a.Allelopathic propensity of the aqueous leaf extract and leaf litter of *Melia dubia* Cav. on pulse crops. Journal of Experimental Biology and Agricultural Sciences, 5(5): 644-655.

Thakur NS, Kumar D. and Gunaga RP.2017b.Transient allelopathic propensity of *Melia composita* Willd. leaf litter on chickpea (*Cicer arietinum*L.). Indian Journal of Ecology*,* 44 (Special Issue-5): 443-450.

Thakur NS, Mohanty S, Hegde HT, Chauhan RS, Gunaga RP and Bhuva DC. 2019. Performance of *Melia dubia* under *Cymbopogon* spp. based agroforestry systems. Journal of Tree Sciences 38(1): 28-34.

Thakur NS, Suvera AH, Jha SK and Patel DB. 2019. Growth performance, essential oil recovery and financial flows of *Ocimum* spp. under *P. pinnata-Ocimum* spp. based silvi-medicinal agroforestry systems. In: Agroforestry for Climate Resilience and Rural Livelihood. (Eds. Dev, et al.). Scientific Publishers, Jodhpur. 335-344.

Thakur NS, Verma KS and Rana RC. 2014. Growth and yield performance of ashwagandha (*Withania somnifera*) under agroforestry. Indian Journal of Agricultural Sciences, 84 (8): 937-941.

Thakur NS, Verma KS and Rana RC. 2011. Effect of tree crop combinations and nitrogen levels on velvet bean (*Mucuna pruriens* L) grown in agri-horti-silvi-pasture system of agroforestry in mid hill Himalayan region. Journal of Non-Timber Forest Products, 18(4): 303-312.

Thakur NS, Jilariya DJ, Gunaga RP and Singh S. 2018. Positive allelospoly of *Melia dubia* Cav. spatial geometry improve quantitative and qualitative attributes of *Aloe vera* L. Industrial Crops and Products, 119:162-171.

Thakur NS, Mohanty S, Gunaga RP and Gajbhiye NA. 2019. *Melia dubia* Cav. spatial geometries influence the growth, yield and essential oil principles content of *C. flexuosus* (Nees Ex Steud.) W. Watson. Agroforestry System DOI 10.1007/s10457-019-00465-6.

Verma A, Saralch S, Chauhan S, Suresh NVM and SrivastavaVarun. 2013. Growth behavior of Poplar (*Populus deltoides*) clones under farm forestry. Indian Forester134 (12): 1079-1083.

Verma SK and Rana BS. 2014. Effect of light intensity on paddy and wheat grain yield under *Eucalyptus tereticornis* Sm. based agri-silviculture system. Indian Forester 140 (1): 23 – 28.

Verma KS, Thakur NS and Rana RC. 2010. Effect of tree crop combinations and nitrogen levels on herbage yield of sacred basil (*Ocimum sanctum* L.) grown in agri-horti-silvi-pasture system in mid hill Himalayas. Indian Journal of Agroforestry, 12(1): 71-76.

Warrier RR, Priyadharsani and Kumar NN. 2012. *Melia dubia* Cav. – A potential indigenous fast growing species for farmlands. Indian Forester 138(6): 567 – 568.

Yadav RP, Bana OPS, Kaushal R. and Rajput RR. 2015. Growth analysis and yield of wheat in North – West India. Indian Forester 141 (3): 313 – 318.

Yadav RP, Sharma P, Arya SL, Panwar P. 2014. *Acacia nilotica* - based silvipastoral systems for resource conservation and improved productivity from degraded lands of the Lower Himalayas. Agroforestry systems 88 (5): 851-863.