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Research Article

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Performance of wheat and mustard in agroforestry system under terai conditions of U.P., India

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ABSTRACT
A large area is available in the form of boundaries, bunds, block plantations, wastelands where this system can be adopted. Poplar and Eucalyptus are suitable and promising agroforestry tree species, which is planted cropping system. In this particular study, Economical aspects and viability of wheat and Mustard have been studied. Trees intercropped with crops attained better growth and higher litter. In the study of nutrients (NPK) it is reviewed that all the three nutrients increase as the age of trees increases. All the nutrients increases as the tree age are increased. It is clearly seen after the whole research work done, nutrients in the soil are high insole plantation of trees. The yield of intercrops is low in the fields which are cultivated along with trees. The height of intercrops is higher under Poplar than intercrops under Eucalyptus. This might be due to the leaf pattern and its canopy shade. No significant results were obtained for tillers per plant and effective tillers per plant in wheat, however, more tillers were found in pure cropping. In Mustard primary branches per plant and seeds per siliqua were at par under Eucalyptus, Poplar, and pure cropping. Yield parameters such as secondary branches per plant, siliqua per plant, and test weight were significantly higher in pure cropping. The grain and straw/stover yields of both the crops under Eucalyptus and Poplar decreased significantly as compared to open fields (crops without Eucalyptus and Poplar). Net returns from a crop grown with Eucalyptus, & Poplar and sole cropping revealed that maximum income (Rs.82819.00/ha) was recorded in pure cropping (monoculture) of wheat, whereas net returns from Mustard grown Eucalyptus, Poplar and sole cropping revealed that maximum income (Rs.67275.00/ha) and whereas negative net returns of Rs.3943.47/ha (under 4years Eucalyptus) and also negative net returns Rs. 8731.00/ha (under 5 years Poplar) was recorded in Mustard oil.
Keywords: Wheat, Mustard, Populus, Eucalyptus and Intercropping.

INTRODUCTION

Natural forests alone cannot meet the demand for fuelwood, timber, and other wood products and have to be supplemented by plantations in farmlands (Evans, 1976). Agroforestry is an integrated land-use system approach, different from the sum of its two major components, viz., agriculture and forestry. The specific advantages of this system are early financial returns, increased cash flow, and improved ecology. Due to overexploitation, unscientific collection, and illegal export, the genetic resources of valuable crops are getting exhausted very fast. To overcome this situation, the crops are being cultivated along with the trees under agroforestry systems. Growing trees on agricultural fields, combined with agricultural crops for augmenting biomass production per unit area is now becoming popular among the farmers. In return, the farmers get the cash crop benefits as also the returns in the form of timber, fuelwood, and fodder, etc. With the high cost of land, growing trees for 20-60 years has now become unduly expensive and needs to be replaced by quick-growing trees. Eucalyptus and Poplar can make an important contribution to this end owing to its rapid growth rate and multiple exploitations. Its importance as an agroforestry tree has been realized (Chaturvedi, 1982 and 1988). Trees on farms can be made popular, especially fast-growing like Eucalyptus and Poplar, which also provide fodder, fuel, and timber. Thus, keeping in view multipurpose uses and roles in bio-drainage Eucalyptus plantation is likely to be adopted on a large scale on government and private lands.

Populus deltoids and Eucalyptus spp. have shown great promise as exotic industrial timber trees and are being planted extensively for wood and pulp production in Northern India. These are fast-growing short rotation trees, which deplete the soil more as compared to slow-growing and long rotation ones (Prasad, et.al.,1985). The potential benefit from growing tree combination

with annual or perennial crops has been suggested by (Nair, 1984). Mustard is an important oilseed crop of family Cruciferae and occupies a prominent place among oilseed crops being next to groundnut in importance. The present area, production, and yield of nine oilseeds in India are around 26.48 mha, 30.94 mt, and 1168 kg/ha respectively. The average productivity of rapeseed mustard in India is only 1145 kg/ha, which needs to be enhanced up to 2562 kg/ha by 2030 for ensuring edible oil self-reliance (DRMR,2011). The country shares about 23% of the world's production of rapeseed and mustard. The oil content of the mustard seeds ranges from 35-48% and 37-42% protein in cake (NIIR, Board and Nagraj, 1995). The present study was, thereforg undertaken to evaluate Growth Performance of Populus deltoides, with the following objectives; l. Effect of tree age and crop variety on growth and yield of wheat in block plantation of poplar. ll. Effect of tree age and crop variety on growth and yield of mustard in block plantation of poplar. lll. Nutritional Studies in litterfall and soil. lV. Economic analysis of poplar-wheat and poplar-mustard agroforestry models

MATERIALS AND METHODS

The field experiments were conducted at a farmer's field in District Pilibhit of Terai and Bhabar region of U.P; India for two years, 2018 and 2019. Maximum and minimum temperature ranges from 22 to 45 C and 8.10 to 28.10 C, respectively. The soil of the site was a Typic Hapludoll derived from alluvium. It is a silty clay loam having a pH of 7.1, Organic Carbon 1.0, available N, P, and K are 271.5, 11.8, and 243.4 kg/ha, respectively.

Four age groups (2, 3, 4 and 5 years) of *Eucalyptus tereticornis* and *Populus deltoids* (S7C8) were selected for the study. *E. tereticornis* and *P. deltoides* were planted at the spacing of 6m x 2m and 4m x 3m (833 trees/ha), respectively. Farmer's who were sowing wheat (HD - 2967) and Mustard (Pant pili sarson–1), with these trees as intercrops and also as pure crop, on more than one acre of land, were chosen for the study.

Two winter season crops viz.; Wheat (HD-2967) Triticum aestivum L.and Mustard (Pant pili sarson–1) Brassica juncea L.were sown in the interspaces of 2,3,4 and 5 years old *Eucalyptus tereticornis* and *Populus deltoids* plantation.

Wheat was sown during the last week of November and Mustard was sown during the second week of October.

Half dose of N and a full dose of P and K and Sulphur as the basal application was given to Mustard crop and half N was applied to the crop as topdressing [N-90; P-40; K-20 and S-30 kg/ha].

Half dose of N and a full dose of P and K were applied to wheat crop as basal application; And 1/4th of N after 1st irrigation, and 1/4th after 2nd irrigation [N-150, P-60, K-40 and Zn-25 kg/ha]. The wheat crop was irrigated after every 22 days, whereas two irrigations were applied in Mustard. Weeding was done manually twice during the crop period. Both the crops (wheat and mustard) were also sown under control conditions (without trees) in the adjacent plot.

The observation was recorded for trees were diameter at breast height (cm) and height (met).

Total litter production (t/ha/yr), total addition of nutrients to the soil through litterfall (kg/ha/yr), and available N.P.K (kg/ha) content of the soil under trees as pure and intercropped with wheat and Mustard at various ages.

The observations were recorded on plant height (cm) at 30, 60, 90 and 120 DAS (days after sowing), of intercrops as well as pure crops; tillers per plant at 40-DAS and effective tillers per plant, spike length, grains per spike, test weight (1000 seed weight), grain yield (q/ha) and straw yield in wheat were recorded at harvest time, of wheat crop.

In Mustard, plant height at 30,60,90 and 120 DAS and Primary branches per plant, secondary branches per plant, pods per plant, seeds per siliqua, test weight, grain, and stover yields were recorded at harvest time.

Photosynthetically active radiation (PAR) reaching the crop surface under the canopy of Eucalyptus and Poplar; and control were measured at three spots 9:30 a.m.; 11:30 a.m.; and 4:30 p.m. with Lux Meter and average was taken as PAR value. Two general precautions were taken in sampling light intensities in vegetation with this device; 1. The face of the photoconductor must be approximately horizontal and facing up, 2. Reading must be taken when the sun is well up in the sky. The data were analyzed by the paired t-test (Fisher, 1948 and Mohsin, 1994).

The diameter of trees was measured at breast height (1.37met.) and height was measured by Ravi Altimeter, each year during the period of study. The annual litterfall production of the trees in intercropping stands was recorded by collecting all the leaves and twigs, falling to the soil surface in litter traps made by demarcating 100cm x 100cm areas at 6 places (two places each at South, North, and Central position of line). The litter samples collected were pooled together to represent annual fall and oven-dried at 80 C for 36 hrs and subjected to further chemical analysis for N, P, K, using the modified micro Kjeldahl, Vanadomolybdophosphoric acid yellow color method and flame photometry, respectively (Jackson, 1967).

The total addition of nutrients to the soil through litterfall (kg/ha/yr) was also calculated. The available nitrogen in the soil was estimated by the method by Subbiah and Asija (1956) using 0.32% KmNo4 and 2.5% boric acid having a mixed indicator.

The available phosphorus in the soil was determined by Olsen's bicarbonate method and the available potassium was extracted from the soil by neutral normal ammonium acetate as described by Jackson (1967). On the basis of nutrient concentration in the litter, the number of nutrients released and periodical addition to the soil was calculated.

For economic evaluation of the system, the cost items include the cost of field preparation and cultivation of

crops, material inputs such as seed and fertilizer, labor cost for different field operations, interest on working capital and rental value of land was calculated on the basis of prevailing market prices in Mandi Samiti.

For net returns Mandi rates of grain and straw/stover were taken as Rs.1735.00 (2018) and Rs.1840.00 (2019); Rs.300.00 (2018) and Rs.350.00 (2019) per quintal for wheat; And Rs.4160.00(2018) and Rs.4025 .00 (2019), Rs.200.00 (2018) and Rs.150.00 (2019) per quintal for Mustard, grains and straw/stover, respectively.

RESULTS AND DISCUSSION

In the present study, the stands were intercropped with wheat and Mustard. The tree spacing, used at 6m x 2m (*Eucalyptus tereticornis*) and 4m x 3m (*Populus deltoids*), was found to be the best suitable spacing and provided easier agricultural operations. The dbh and height at different ages of trees in pure as well as in intercropped fields are given in Table-1.

Table 1. Performance of Tree components affected by Intercrops

Treatments/	Diameter (cm)				Height (met)			
Age(yrs.)	2	3	4	5	2	3	4	5
Eucalyptus (Pure)	2.5	6.6	10.5	13.1	6.2	9.8	13.9	17.1
Eucalyptus + Wheat	3.8	8.2	12.6	14.9	6.6	11.1	14.7	19.4
Eucalyptus + Mustard	4.6	9.1	13.7	15.6	7.2	11.7	15.6	20.2
Poplar (Pure)	6.5	11.4	15.7	18.9	9.8	11.1	15.2	19.8
Poplar+ Wheat	7.6	12.8	17.2	21.3	11.4	13.2	17.5	20.9
Poplar+ Mustard	8.2	14.1	19.4	22.8	11.9	14.6	19.1	21.6

Table 2. Total Litter Production (t/ha/yr ± SE) as affected by age and treatments

Treatments/ Age (yrs)	2	3	4	5
Eucalyptus (Pure)	0.68 ±0.012	2.31 ±0.034	4.12 ±0.41	6.14 ±0.36
Eucalyptus+Wheat	0.83 ±0.014	2.90 ±0.038	5.24 ±0.44	6.38 ±0.46
Eucalyptus+Mustard	0.96 ±0.018	3.22 ±0.045	6.14 ±0.48	7.15 ±0.54
Poplar (Pure)	1.43 ±0.022	2.61 ±0.035	4.84 ±0.38	6.03 ±0.40
Poplar+Wheat	1.88 ±0.028	3.16 ±0.034	5.26 ±0.38	6.52 ±0.46
Poplar+Mustard	1.94 ±0.027	3.26 ±0.037	5.42 ±0.42	6.58 ±0.44

The speedy growth of the trees under agroforestry is the fact that trees under this system are able to utilize nutrition and cultural operations given to intercrop under them. Therefore, it has been seen, trees grown under agroforestry attained better growth as compared to those grown in forest conditions (Singh et.al., 1988, Ahmed, 1989 and Mohsin, 2015). Soil cultivation is also beneficial to plantations even if no intercrops are grown. Pourtet (1961) has observed that differences in the intensity of cultural methods even in the same plant species alone resulted in growth differences up to 300%. Prevasto and Sekawin (1979) have pointed out that frequent tillage was a must for the good growth of trees, even if no intercrops were grown. Similar studies are in conformity to Puri and Khara, 1991 and Narwal, 1994.

Table 3. Total addition of nutrients to the soil through litterfall (kg/ha/yr) of tree components as affected by age and treatments

Treatments/ Age (yrs)	2	3	4	5
	N			
Eucalyptus (Pure)	5.74	16.18	24.56	28.71
Eucalyptus+Wheat	6.58	18.46	27.24	35.07
Eucalyptus+Mustard	8.24	23.67	32.54	43.46
CD(a) 1%for stand age	1.092			
CD(b) 1%for spp.	1.635			
CD(a x b) 1%	3.271			
	P			
Eucalyptus (Pure)	0.42	0.98	1.91	2.72
Eucalyptus+Wheat	0.48	1.19	2.26	2.96
Eucalyptus+Mustard	0.64	1.82	3.07	3.64
CD(a) 1%for stand age	0.436			
CD(b) 1%for spp.	0.638			
CD(a x b) 1%	1.238			
	K			
Eucalyptus (Pure)	4.70	13.84	21.48	26.11
Eucalyptus+Wheat	5.23	15.56	28.31	32.43
Eucalyptus+Mustard	6.76	21.44	35.78	43.15
CD(a) 1%for stand age	0.668			
CD(b) 1%for spp.	1.004			
CD(a x b) 1%	2.008			
	N			
Poplar (Pure)	14.87	22.96	25.62	28.94
Poplar+Wheat	17.65	25.38	27.25	33.17
Poplar+Mustard	25.86		33.26	
	29.51		41.35	
CD(a) 1%for stand age	0.678			
CD(b) 1%for spp.	1.017			
CD(a x b) 1%	2.035			
	P			
Poplar (Pure)	1.51	2.47	3.71	4.94
Poplar + Wheat	1.81	2.78	3.94	5.57
Poplar +Mustard	2.58	3.79	4.32	6.80
CD(a) 1%for stand age	0.176			
CD(b) 1%for spp.	1.073			
CD(a x b) 1%	2.146			
	K			
Poplar (Pure)	10.43	16.96	24.46	30.58
Poplar+Wheat	12.47	19.11	27.32	34.82
Poplar +Mustard	18.23	26.54	35.61	43.89
CD(a) 1%for stand age	0.815			
CD(b) 1%for spp.	1.222			
CD(a x b) 1%	2.445			

The total annual litter production (t/ha/yr) was low in the sole plantation in comparison to intercrop. The difference in total litter production in the sole and intercropped stands was not significant. The litter production was lower in the juvenile stands but it increased significantly ($P< 0.05$) in the adult ages. This increase in litter production was due to an increase in the number of branches, twigs, and leaves of the trees with the advancing age of the stands. (Saxena and Singh, 1978, Siddhu and Hans, 1988, Mohsin, 2005 and Mohsin and Singh, 2007).

The available N, P, K contents (kg/ha) of soil under the pure stands were found to be higher than the soil of the intercropped stands. Most of the N (33-34%) and K (29-31%) contents were found to be the maximum in the upper strata (0-15cm) of soil. However, most of the P (22-26%) was accumulated in the soil at the depth of 15-30 cm. This was due to the washing effect of the P already available in the upper strata (0-15cm) of the soil

Table 4. Available N.P.K (Kg/ha) content of soil under *Eucalyptus*, as pure and intercropped with Wheat and Mustard

Depth of Soil (cm)	Species Mixture Pure	Euc + wheat	Euc + mustard	Pure	Euc + wheat	Euc + mustard	Pure	Euc + wheat	Euc + mustard	Pure	Euc + wheat	Euc + mustard
					Age of Eucalyptus (Years)							
	2			3			4			5		
						N						
0-15	418.2	350.5	372.1	422.2	356.0	379.2	427.2	363.4	385.1	432.4	371.2	392.2
	(34.8)	(34.8)	(34.2)	(34.2)	(34.2)	(33.7)	(33.9)	(33.6)	(33.2)	(33.2)	(33.1)	(32.6)
15-30	231.6	188.8	211.2	236.6	194.2	217.2	240.8	201.4	223.1	242.4	208.2	229.4
	(19.3)	(18.7)	(19.5)	(19.1)	(18.6)	(19.3)	(19.1)	(18.6)	(19.2)	(18.6)	(18.6)	(19.1)
30-45	181.2	168.2	175.4	186.4	174.4	182.4	192.2	179.8	187.2	199.4	185.2	194.4
	(15.1)	(16.7)	(16.2)	(15.1)	(16.6)	(16.2)	(15.2)	(16.6)	(16.1)	(15.3)	(16.5)	(16.2)
45-60	157.8	132.1	142.5	164.4	137.1	148.9	168.4	144.1	154.2	172.5	151.2	162.8
	(13.1)	(13.1)	(13.2)	(13.3)	(13.1)	(13.2)	(13.3)	(13.3)	(13.3)	(13.2)	(13.5)	(13.5)
60-75	114.2	88.5	96.4	121.2	94.4	104.4	125.4	101.0	111.8	134.4	107.2	121.4
	(9.5)	(8.7)	(8.9)	(9.8)	(9.1)	(9.2)	(9.9)	(9.3)	(9.6)	(9.3)	(9.5)	(10.1)
75-90	96.1	78.2	82.2	103.4	85.2	91.2	105.2	90.8	97.8	118.4	96.6	102.2
	(8.0)	(7.7)	(7.6)	(8.3)	(8.1)	(8.1)	(8.3)	(8.4)	(8.4)	(9.1)	(8.6)	(8.5)
Total	1199.1	1006.3	1079.8	1234.2	1040.3	1123.2	1259.5	1080.5	1159.2	1299.5	1119.6	1202.4
						P						
0-15	18.6	13.4	16.2	21.6	16.8	19.2	24.6	18.4	22.2	27.8	22.6	25.4
	(23.5)	(22.8)	(23.9)	(22.1)	(21.4)	(21.7)	(20.9)	(20.4)	(20.6)	(20.2)	(19.4)	(20.3)
15-30	21.2	15.8	18.9	24.4	20.6	22.4	28.2	23.2	25.8	32.2	27.0	28.6
	(26.8)	(26.9)	(27.9)	(25.0)	(26.2)	(25.3)	(23.9)	(24.4)	(24.0)	(23.4)	(23.2)	(22.9)
30-45	14.5	11.6	12.4	17.8	14.6	16.1	20.6	17.8	19.2	23.6	21.8	21.4
	(18.3)	(19.8)	(18.3)	(18.2)	(18.6)	(18.2)	(17.5)	(18.7)	(17.8)	(17.1)	(18.7)	(17.9)
45-60	10.8	7.6	9.0	14.0	10.4	12.4	17.2	13.4	15.4	21.0	17.2	18.6
	(13.6)	(13.0)	(13.2)	(14.3)	(13.2)	(14.0)	(14.6)	(14.1)	(14.3)	(15.2)	(14.8)	(14.9)
60-75	7.8	5.8	6.2	10.6	8.6	9.8	13.8	11.2	12.9	16.9	14.5	15.4
	(9.8)	(9.9)	(9.1)	(10.8)	(10.9)	(11.1)	(11.7)	(11.7)	(12.0)	(12.2)	(12.4)	(12.3)
75-90	6.0	4.4	5.0	9.2	7.4	8.4	13.2	10.0	11.8	16.1	13.1	14.2
	(7.6)	(7.5)	(7.3)	(9.4)	(9.4)	(9.5)	(11.2)	(10.5)	(10.9)	(11.9)	(11.2)	(11.4)
Total	78.9	58.6	67.7	97.6	78.4	88.3	117.6	95.0	107.3	137.6	116.2	124.6
						K						
0-15	280.2	263.6	272.4	286.4	268.6	277.4	293.4	274.4	284.2	299.2	282.1	285.4
	(31.4)	(32.6)	(31.9)	(30.8)	(31.7)	(31.1)	(30.2)	(31.1)	(30.6)	(29.4)	(30.4)	(29.7)
15-30	199.6	183.5	192.4	204.2	190.1	199.1	212.6	196.2	204.6	222.6	203..2	211.3
	(22.4)	(22.7)	(22.5)	(21.9)	(22.4)	(22.3)	(21.9)	(22.2)	(22.1)	(21.9)	(21.9)	(22.0)
30-45	138.4	124.4	131.2	145.2	131.8	137.4	151.4	137.2	143.3	158.2	143.4	148.6
	(15.5)	(15.4)	(15.3)	(15.6)	(15.5)	(15.4)	(15.6)	(15.5)	(15.4)	(15.5)	(15.5)	(15.5)
45-60	116.2	103.5	111.4	121.4	110.4	117.5	128.0	117.1	122.0	134.2	123.2	128.2
	(13.0)	(12.8)	(13.0)	(13.0)	(13.0)	(13.2)	(13.1)	(13.2)	(13.1)	(13.2)	(13.3)	(13.3)
60-75	88.4	74.5	82.4	95.6	81.2	88.1	102.4	87.2	96.4	108.2	96.2	101.4
	(9.9)	(9.2)	(9.6)	(10.2)	(9.5)	(9.8)	(10.5)	(9.8)	(10.4)	(10.6)	(10.3)	(10.5)
75-90	68.2	57.5	64.2	76.8	64.5	71.2	83.2	71.2	77.4	92.2	78.4	84.5
	(7.6)	(7.1)	(7.5)	(8.2)	(7.6)	(7.9)	(8.5)	(8.1)	(8.3)	(9.1)	(8.4)	(8.8)
Total	891.0	807.0	854.0	929.6	846.6	890.7	971.0	883.3	927.9	1014.6	926.5	959.4

*Values in parantheses indicate the percent of the nutrients at various depth of soil.

and the Padded through litterfall. The type of vegetation grown under the tree also reflected soil property (Jacques et.al., 1975 and Seth et.al. 1963). Therefore the available nutrients were found to be higher in the soil of the stands intercropped.

Table 5. Available N.P.K (Kg/ha) content of soil under *Poplar*, as pure and intercropped with Wheat and Mustard

Depth of Soil (cm)	Species Mixture											
	Pure	Pop + wheat	Pop + mustard	Pure	Pop + wheat	Pop + mustard	Pure	Pop + wheat	Pop + mustard	Pure	Pop + wheat	Pop + mustard
	Age of Eucalyptus (Years)											
	2			3			4			5		
							N					
0-15	428.0 (34.8)	379.0 (33.5)	392.0 (33.6)	432.8 (34.5)	383.5 (33.1)	396.2 (33.2)	436.4 (34.1)	387.2 (32.7)	398.4 (32.8)	441.5 (33.8)	391.4 (32.4)	412.6 (32.9)
15-30	234.0 (19.0)	216.8 (19.1)	225.2 (19.3)	237.6 (18.9)	224.6 (19.4)	229.8 (19.2)	242.2 (18.9)	229.2 (19.4)	232.6 (19.2)	246.2 (18.8)	233.4 (19.3)	236.8 (18.9)
30-45	187.5 (15.2)	181.8 (16.1)	183.4 (15.7)	192.2 (15.3)	185.2 (16.0)	187.8 (15.7)	197.4 (15.4)	189.2 (16.0)	191.2 (15.7)	202.2 (15.4)	193.4 (16.0)	198.2 (15.8)
45-60	162.6 (13.2)	155.5 (13.7)	158.1 (13.5)	165.4 (13.1)	160.2 (13.8)	164.6 (13.8)	170.2 (13.2)	165.4 (14.0)	168.6 (13.5)	176.8 (14.0)	169.8 (14.0)	175.6 (14.1)
60-75	118.4 (9.6)	105.2 (9.3)	110.5 (9.5)	123.2 (9.8)	108.4 (9.3)	114.2 (9.5)	127.4 (9.9)	111.8 (9.5)	118.2 (9.7)	128.2 (9.8)	115.2 (9.5)	123.4 (9.8)
75-90	99.2 (8.1)	91.4 (8.1)	95.4 (8.1)	103.. 8 (8.2)	93.8 (8.1)	99.6 (8.3)	107.6 (8.4)	98.2 (8.3)	103.4 (8.5)	111.4 (8.5)	102.4 (8.4)	105.2 (8.4)
Total	1229.7	1129.7	1164.6	1255.0	1155.7	1192.2	1281.2	1181.0	1212.4	1306.3	1205.6	1251.8
							P					
0-15	21.4 (21.8)	18.0 (21.2)	19.2 (21.2)	23.2 (19.4)	20.2 (20.7)	21.4 (20.4)	26.8 (19.3)	22.6 (20.1)	24.8 (19.9)	29.4 (19.1)	25.4 (20.1)	27.2 (19.4)
15-30	24.2 (24.6)	21.8 (25.9)	22.4 (24.8)	29.4 (24.6)	23.6 (24.1)	24.2 (23.1)	33.4 (24.0)	25.8 (22.9)	28.2 (22.7)	37.2 (24.2)	28.6 (22.5)	33.2 (23.6)
30-45	18.6 (18.9)	15.0 (17.8)	17.2 (19.0)	21.2 (17.8)	18.2 (18.6)	19.8 (18.8)	22.8 (16.4)	20.6 (18.3)	22.2 (17.8)	24.4 (15.8)	22.8 (18.0)	23.8 (16.9)
45-60	13.2 (13.4)	11.8 (14.1)	12.5 (13.8)	17.4 (14.6)	13.4 (13.7)	15.2 (14.5)	20.4 (14.7)	16.2 (14.4)	18.8 (15.1)	23.0 (14.9)	18.6 (14.7)	21.0 (14.9)
60-75	11.4 (11.6)	9.8 (11.6)	10.2 (11.3)	15.5 (13.0)	12.0 (12.3)	12.8 (12.2)	18.8 (13.5)	14.4 (12.8)	15.9 (12.7)	20.6 (13.3)	16.8 (13.2)	17.9 (12.7)
75-90	9.2 (9.4)	7.6 (9.1)	8.8 (9.7)	12.4 (10.4)	10.2 (10.4)	11.4 (10.8)	16.6 (11.9)	12.6 (11.2)	14.4 (11.5)	19.2 (12.4)	14.4 (11.3)	17.2 (12.2)
Total	98.0	84.0	90.3	119.1	97.6	104.8	138.8	112.2	124.3	153.8	126.6	140.3
							K					
0-15	289.2 (26.2)	275.2 (28.5)	280.4 (27.4)	293.4 (25.8)	279.8 (28.1)	285.2 (27.1)	299.6 (25.7)	283.6 (27.6)	290.1 (26.8)	305.8 (24.6)	292.8 (26.9)	296.2 (26.0)
15-30	209.4 (19.0)	198.4 (20.5)	206.2 (20.2)	213.2 (18.8)	203.6 (20.4)	208.4 (19.7)	218.2 (18.7)	208.4 (20.3)	213.4 (19.7)	231.4 (18.8)	219.4 (20.2)	228.2 (20.0)
30-45	185.5 (16.8)	161.4 (16.7)	172.6 (16.9)	190.2 (16.7)	166.8 (16.7)	180.2 (17.1)	195.4 (16.8)	172.4 (16.8)	183.8 (16.9)	210.6 (16.9)	178.8 (16.4)	191.4 (16.8)
45-60	172.4 (15.6)	142.4 (14.7)	150.2 (14.7)	178.4 (15.7)	147.5 (14.8)	156.1 (15.6)	182.2 (14.8)	152.4 (14.9)	160.2 (16.0)	199.2 (15.2)	165.2 (15.1)	172.4 (15.4)
60-75	132.6 (12.0)	98.6 (10.2)	116.4 (11.4)	139.4 (12.3)	103.4 (10.4)	122.4 (11.6)	144.5 (12.4)	109.2 (10.6)	128.9 (11.9)	158.6 (12.7)	119.8 (11.0)	131.2 (11.5)
75-90	112.5 (10.2)	88.2 (9.1)	95.1 (9.3)	118.5 (10.4)	93.4 (9.4)	101.2 (9.6)	124.2 (10.6)	98.8 (9.6)	106.5 (9.8)	135.1 (10.8)	110.2 (10.1)	119.8 (10.5)
Total	1101.6	964.2	1020.9	1133.1	994.5	1053.5	1164.1	1024.8	1082.9	1240.7	1086.2	1139.2

*Values in parantheses indicate the percent of the nutrients at various depth of soil.

Table 6A. Effect of Poplar on Monthly Plant Height of Wheat and Mustard

DAS	Plant Height (cm)											
	WHEAT						*MUSTARD*					
	With out *Poplar*	With *Poplar* Age (years)				Paired t-test value	Without *Poplar*	With *Poplar* Age (years)				Paired t- test value
		2	3	4	5			2	3	4	5	
30	9.9 ±1.48	9.2 ±1.48	7.3 ±1.52	5.8 ±1.68	4.6 ±1.46	2.58	68.7 ±2.81	24.4±2.84	21.1±2.81	16.2±2.81	14.2 ±2.82	16.38*
60	37.7 ±0.48	36.6±0.48	28.2±0.68	21.7 ±0.72	16.4 ±0.46	1.94	140.7 ±8.10	48.0±8.16	45.4±8.12	30.6±8.10	14.5 ±8.14	11.35*
90	65.4 ±2.02	55.6±2.02	50.4±2.06	41.2 ±2.08	37.4 ±2.04	4.43*	168.6 ±3.31	71.4±3.34	67.3±3.31	59.3±3.32	42.2 ±3.32	31.81*
120	96.5 ±0.96	79.2±0.96	68.1±0.98	64.4 ±0.92	62.1 ±0.86	27.67*	175.5 ±1.15	79.6±1.19	67.7±1.17	62.4±1.16	53.2 ±1.16	91.80*

*P ≤ 0.05

Table 6B. Effect of Eucalypts on Monthly Plant Height of Wheat and Mustard

	Plant Height (cm)											
	WHEAT						MUSTARD					
DAS	With out Eucalypts	With Eucalypts Age (years)				Paired t-test value	With out Eucalypts	With Eucalypts Age (years)				Paired t-test value
		2	3	4	5			2	3	4	5	
30	9.9 ±1.45	8.8 ±1.46	6.2 ±1.52	5.3 ±1.66	4.1 ±1.44	2.62	68.7 ±2.83	22.5 ±2.86	18.4 ±2.14	15.8 ±2.79	13.6 ±2.85	16.42*
60	37.7 ±0.46	35.4 ±0.48	19.5 ±0.72	16.8 ±0.82	12.1 ±0.46	1.84	140.7 ±8.12	46.7 ±8.16	43.1 ±8.16	39.9 ±8.11	36.2 ±8.14	11.32*
90	65.4 ±2.02	46.9 ±2.04	42.8 ±2.04	38.1 ±2.06	32.4 ±2.04	4.32*	168.6 ±3.33	67.1 ±3.36	62.2 ±3.35	46.5 ±3.38	32.4 ±3.32	32.46*
120	96.5 ±0.98	60.4 ±0.98	56.4 ±0.94	51.6 ±0.92	46.8 ±0.86	27.67*	175.5 ±1.17	71.2 ±1.19	64.4 ±1.12	57.4 ±1.12	51.8 ±1.18	92.40*

*P ≤ 0.05, DAS. Days After Sowing

Brassica does not have root nodules but being a broad-leafed plant, it takes fewer nutrients from the soil as compared to wheat. Perhaps, Eucalyptus is more detrimental to soil due to its more water absorption and evaporating property and essential oil in leaves that fall on soil and are harmful to soil microflora. Similar findings in relation to available nutrients have been reported from different strata of the soil under the Eucalyptus hybrid pure as well as intercropped with Aromatic grasses (Singh et.al.,1989), E. globules, and Black wattle plantations (Venkataramanan et.al., 1983, Mohsin and BabuRam 2002, Mohsin and Singh,2003 and Mohsin and Singh, 2007). Higher grain yield has been recorded in pure fields than intercropped with Eucalyptus. Similar studies were in conformity to Kumar, et. al. 1998; Prasad, et. al. 2010; Kumar, et. al. 2013 and Dhillon, et. al., 2016.

The plant height of wheat at 30 and 60 DAS did not differ significantly under Eucalyptus and Poplar and in open (pure wheat). However, at later stages (90 and 120 DAS) it was significantly less under trees as compared to pure cropping. It is due to advanced germination under trees. Plant height of wheat and Mustard was found to be higher in intercropped with Poplar in comparison to Eucalyptus, at 30, 60, 90, and 120 DAS, at each age of Eucalyptus and Poplar. Maximum plant height (96.5 cm) was recorded in pure cropping (Table 6.). Significantly less plant height of mustard was recorded under trees as compared to pure cropping.

Table 7. Effect of Eucalyptus and Poplar on Yield parameters of Wheat and Mustard, with age of 2,3,4,5 years

Yield parameters	**With out Euc**	**With Euc**	**Paired t-test value**	**Without Pop**	**With Pop**	**Paired t-test value**	**With out Euc**	**With Euc**	**Paired t-test value**	**Without Pop**	**With Pop**	**Paired t-test value**
WHEAT	2 Years						3 Years					
Plants/ running met.row length at	190.0 ±2.06	171.7 ±2.06	5.7*	190.0 ±2.06	183.6 ±2.08	5.6*	190.0 ±2.06	159.6 ±2.08	5.4*	190.0 ±2.06	171.6 ±2.07	5.6*

15 DAS												
Tillers/plant at 40 DAS	7.6 ±0.89	6.2 ±0.89	1.8	7.6 ±0.89	6.9 ±0.79	1.6	7.6 ±0.89	4.8 ±0.84	1.7	7.6 ±0.89	6.2 ±0.92	1.8
Effective tillers/plant at harvesting	5.9 ±1.09	4.6 ±1.09	1.2	5.9 ±1.09	5.1 ±1.07	1.4	5.9 ±1.09	3.7 ±1.07	1.3	5.9 ±1.09	4.3 ±1.04	1.6*
Spike length cm	10.2 ±0.38	8.4 ±0.38	13.8*	10.2 ±0.38	9.3 ±0.36	13.4*	10.2 ±0.38	7.6 ±0.34	13.8*	10.2 ±0.38	8.3 ±0.42	13.2*
Grains/spike	53.4 ±6.75	39.1 ±6.75	6.5*	53.4 ±6.75	42.8 ±6.55	6.7*	53.4 ±6.75	37.2 ±6.85	6.4*	53.4 ±6.75	38.4 ±6.36	6.5*
Total weight gm	33.6 ±2.7	27.2 ±2.7	3.6*	33.6 ±2.7	29.6 ±2.9	3.6*	33.6 ±2.7	25.4 ±2.9	3.4*	33.6 ±2.7	26.7 ±2.9	3.4*
*P≤ 0.05							*P≤ 0.05					
MUSTARD												
Primary branches/ plant	8.8 ±2.30	6.2 ±2.30	1.49	8.8 ±2.30	7.6 ±2.40	1.49	8.8 ±2.30	5.4 ±2.40	1.47	8.8 ±2.30	7.1 ±2.47	1.47
Secondary branches/ plant	18.6 ±1.87	7.6 ±1.87	7.94*	18.6 ±1.87	11.4 ±1.93	7.92*	18.6 ±1.87	6.5 ±1.89	7.96*	18.6 ±1.87	9.9 ±1.99	7.82*
Siliqua/plant	382.0 ±8.50	96.2 ±8.50	35.76*	382.0 ±8.50	108.6 ±8.70	35.78*	382.0 ±8.50	94.7 ±8.60	35.78*	382.0 ±8.50	101.6 ±8.70	35.76*
Seeds/ siliqua	16.5 ±1.63	11.7 ±1.63	4.07	16.5 ±1.63	13.5 ±1.43	4.09	16.5 ±1.63	9.4 ±1.83	4.05	16.5 ±1.63	11.8 ±1.73	5.03
Test weight gm	10.8 ±0..03	7.2 ±0.03	12.74*	10.8 ±0.03	8.6 ±0.05	12.84*	10.8 ±0..03	6.3 ±0.05	12.64*	10.8 ±0.03	7.8 ±0.07	12.94*
*P≤ 0.05							*P≤ 0.05					
WHEAT	4 Years						5 Years					
Plants/ running met.row length at 15 DAS	190.0 ±2.06	142.4 2.02	5.8*	190.0 ±2.06	165.4 ±2.04	6.2*	190.0 ±2.06	128.2 2.08	5.6*	190.0 ±2.06	141.4 ±2.10	5.4*
Tillers/plant at 40 DAS	7.6 ±0.89	3.6 0.71	1.5	7.6 ±0.89	4.9 ±0.82	1.9	7.6 ±0.89	1.8 0.61	1.4	7.6 ±0.89	3.2 ±0.63	1.4
Effective tillers/plant at harvesting	5.9 ±1.09	2.5 1.02	1.3	5.9 ±1.09	3.1 ±1.04	1.5	5.9 ±1.09	1.4 1.06	1.1	5.9 ±1.09	2.7 ±1.06	1.3
Spike length cm	10.2 ±0.38	5.7 1.92	13.6*	10.2 ±0.38	6.9 ±1.88	13.2*	10.2 ±0.38	3.9 1.86	14.6*	10.2 ±0.38	4.2 ±1.87	15.2*
Grains/spike	53.4 ±6.75	33.1 7.71	6.2*	53.4 ±6.75	35.2 ±7.76	6.8*	53.4 ±6.75	26.4 7.81	7.6*	53.4 ±6.75	29.7 ±7.81	6.8*
Total weight gm	33.6 ±2.7	23.2 3.7	3.2*	33.6 ±2.7	24.7 ±3.5	3.4*	33.6 ±2.7	18.4 3.5	4.2*	33.6 ±2.7	21.2 ±3.5	4.4*
*P≤ 0.05							*P≤ 0.05					
MUSTARD												
Primary branches/ plant	8.8 ±2.30	3.2 ±2.04	1.49	8.8 ±2.30	5.2 ±2.04	1.51	8.8 ±2.30	1.6 ±2.09	1.72	8.8 ±2.30	3.2 ±2.09	1.81
Secondary branches/ plant	18.6 ±1.87	4.9 ±0.61	7.92*	18.6 ±1.87	8.1 ±0.61	8.42*	18.6 ±1.87	2.7 ±0.51	8.62*	18.6 ±1.87	5.3 ±0.51	8.74*
Siliqua/plant	382.0 ±8.50	91.5 ±8.52	34.88*	382.0 ±8.50	97.2 ±8.54	35.66*	382.0 ±8.50	82.2 ±8.42	37.76*	382.0 ±8.50	89.4 ±8.44	37.56*
Seeds/ siliqua	16.5 ±1.63	7.1 ±1.64	4.07	16.5 ±1.63	11.0 ±1.65	5.05	16.5 ±1.63	5.7 ±1.52	7.07	16.5 ±1.63	7.8 ±1.52	5.07
Test weight gm	10.8 ±0..03	4.6 ±0.05	12.74*	10.8 ±0..03	7.1 ±0.07	14.84*	10.8 ±0..03	3.2 ±0.05	14.60*	10.8 ±0..03	5.6 ±0.05	14.82*
*P≤ 0.05							*P≤ 0.05					

Table 8. Effect of Eucalyptus and Poplar at various ages on Grain, Straw Yield, Cultivation Cost and Net Returns of Wheat

Parameters	**Without Euc.**	**With Eucalyptus**				**Without Popular**	**With Poplar**			
		2018	**2019**				**2018**	**2019**		
		2	3	4	5		2	3	4	5
Wheat grain q/ha	52.4	47.6	43.1	36.8	32.1	52.4	48.7	45.6	39.7	35.2
Straw q/ha	62.6	51.5	47.2	42.4	38.5	62.6	52.3	49.4	41.0	39.2
Cost of cultivation Rs./ha.	26,875	26,875	26,875	26,875	26,875	26,875	26,875	26,875	26,875	26,875
Profit grains Rs./ha.	90,914	82,586	74,778.50	67,712	59,064	90,914	84,494.50	79,116	73,048	64,768
Profit straw Rs./ha.	18,780	15,450	14,160	14,840	13,475	18,780	15,690	14,820	14,350	13,720
Price-Grain Rs./q	1,735	1,735	1,735	1,840	1,840	1,735	1,735	1,735	1,840	1,840
Price-Straw Rs./q	300	300	300	350	350	300	300	300	350	350
Total Profit Rs./ha.	109694	98,036	88,938.50	82,552	72,539	109694	100184.50	93,936	87,398	78,488
Net Profit Rs./ha.	82,819	71,161	62,063.50	55,677	45,664	82,819	73,309.50	67,061	60,523	51,613

Table 9. Effect of Eucalyptus and Poplar at various ages on Grain, Strover Yield, Cultivation Cost and Net Returns in INR of Mustard

Parameters	**Without *Euc.***	**With *Eucalyptus***				**Without *Pop.***	**With *Poplar***			
		2018	**2019**				**2018**	**2019**		
		2	**3**	**4**	**5**		**2**	**3**	**4**	**5**
Mustard grain q/ha	16.25	11.24	8.51	6.46	5.11	16.25	14.11	11.25	9.62	7.56
Stover yield q/ha	59.93	43.64	35.61	29.25	22.78	59.93	54.46	44.10	37.75	31.64
Cost of cultivation Rs./ha.	19,580.00	19,580.00	19,580.00	19,580.00	19,580.00	19,580.00	19,580.00	19,580.00	19,580.00	19,580.00
Profit grains Rs./ha.	67,600.00	46,758.00	35,401.00	26,001.00	20,567.50	67,600.00	58,967.00	46,800.00	38,720.00	30,429.00
Profit strove Rs./ha.	11,986.00	8,728.00	7,122.00	4,387.50	3,417.00	11,986.00	10,892.00	8,820.00	5,662.50	4,746.00
Price-Grain Rs./q	4,160.00	4,160.00	4,160.00	4,025.00	4,025.00	4,160.00	4,160.00	4,160.00	4,025.00	4,025.00
Price-Strover Rs./q	200.00	200.00	200.00	150.00	150.00	200.00	200.00	200.00	150.00	150.00
Oil Yield Kg/ha	747.50	397.89	265.51	171.83	103.63	747.50	533.35	383.62	275.13	176.90
Oil Content %	46%	35.4%	31.2%	26.6%	21.5%	46%	37.8%	34.1%	28.6%	23.4%
Price of Oil Rs/Kg	90	90	90.00	91.00	91.00	90.00	90.00	90.00	91.00	91.00
Total Profit Oil Rs	67,275	35,810.00	23,895.90	15,636.53	9,430.00	67,275.00	48,001.50	34,525.80	25,036.80	16,097.90
Net Profit Grain Rs./ha.	48,020	27,178.00	15,821.00	6,421.00	987.75	48,020.00	39,117.00	27,220.00	19,140.00	10,849.00
Net Profit Oil Rs./ha.	47,695	16,230.00	4,315.90	-3943.47	-10,150.00	47,695.00	28,421.50	14,945.80	5,456.80	-8,731.00

Less height of crops under trees may be primarily due to reduced light intensity under trees. The data recorded during the experiment in the month of December has clearly shown that PAR available to crops under Eucalyptus was 36.45, 41.28 and 47.21% at 3 years age and under Poplar, at the age of 3 Years it was 41.26, 45.24 and 53.26% at 10:00 AM,12:30 PM and 4:00 PM, respectively of light available to crops in open. Thus, more light intensity in sole cropping increased the photosynthetic efficiency of crops resulting in better growth as reported by Wassink (1954) and

Photosynthetic efficiency of crops resulting in better gror, rrttr as reported by Mohsin (1994).

The other parameters such as plants per running meter row length (171.7), spike length (8.4), grains per spike (39.1), and test weight (27.2 gm) were significantly less under Eucalyptus than in sole cropping at the age of 2 years. These values were on the higher side, intercropped with poplar at 2 years. Similar patterns were observed in intercrops with 3, 4 and 5 years of trees.

However, in Mustard primary branches per plant and seeds per siliqua were at par under Eucalyptus, Poplar, and pure cropping. Yield parameters such as secondary branches per plant, siliqua per plant, and test weight were significantly higher in pure cropping. The numbers of secondary branches recorded in pure cropping were 18.6 as compared to 7.6 under Eucalyptus and 11.4 under Poplar under 2 years of age.

Similar patterns were also seen with 3,4- and 5-Years trees. The corresponding values of siliqua per plant and test weight were 382.0, 10.8gm in pure cropping and 96.2, 7.2gm under 2 years age of Eucalyptus and in Poplar (2 years) it was found 108.6 and 8.6 gm, respectively. Under the age of 3,4 and 5 years of Eucalyptus and Poplar it was 94.7,6.3gm and 101.6,7.8 gm; 91.5,4.6gm and 97.2,7.1 gm; and 82.2,3.2gm and 89.4,5.6 gm, respectively (Table 7.).

Reduced value of yield parameters of wheat and Mustard may be ascribed to competition for light, moisture, and nutrients in addition to the allelopathic effect of Eucalyptus and Poplar (Prasad, et. al. 2011). The grain and straw/stover yields of both the crops under Eucalyptus and Poplar decreased significantly as compared to open fields (crops without Eucalyptus and Poplar) and 9.16 to 38.7% and 7.06 to 32.82% grain yield reduction was observed in wheat (Table-8). The decrease in the straw yield of wheat was in the order of 17.73 to 38.49% (Eucalyptus) and 16.45 to 37.38% (Poplar), respectively; while of Mustard (Table-9), it was 30.83 to 68.55% and 13.16 to 53.47% grain yield reduction was observed. The decrease in stover yield of Mustard was in the order of 27.18 to 61.98 % (Eucalyptus) and 9.12 to 47.20% (Poplar). Mohsin et. al., 2020 observed that the total root biomass decreased continuously with increasing soil depth at all the radial distances and under all the age groups. It is clear that there is no completion among the root system with roots of intercrops grown along with Poplar and Eucalyptus.

Yield reduction in wheat and Mustard indicated that higher tree density (833 trees/ha) had a more suppressing effect on crops, reduced solar radiation on crop canopy, and lower availability of moisture and nutrients. Light intensity in Wheat and Mustard under Eucalyptus and Poplar reduced, as compared to pure crops. The reduced yield of groundnut under Teak due to reduced PAR availability has also been recorded by Venkatarao et. al, 2006. Similar studies were in conformity to Mohsin, 1994.

The moisture content under Eucalyptus (4.96%) and Poplar (3.89%) and in open (9.66%) was also recorded and the data indicated that Eucalyptus trees had severe competition for moisture with wheat and mustard. A similar reduction in the yield of wheat in association with Eucalyptus due to moisture competition has also been reported by Deswal and Nandal (2006). Similar studies are in confirmation with the study of Aromatic plants with Poplar and Eucalyptus at various ages in the Terai of U.P. (Mohsin, 1994).

Net returns from a crop grown with Eucalyptus, & Poplar and sole cropping revealed that maximum income (Rs.82819.00/ha) was recorded in pure cropping (monoculture) of wheat, whereas net returns from Mustard grown Eucalyptus, & Poplar and sole cropping revealed that maximum income (Rs.67275.00/ha.) and whereas negative net returns of Rs.3943.47/ha (under 4years Eucalyptus) and also negative net returns Rs. 8731.00/ha (under 5 years Poplar) was recorded in Mustard oil.

CONCLUSION

A large area is available in the form of boundaries, bunds, block plantations, wastelands where this system can be adopted. Poplar and Eucalyptus are suitable and promising agroforestry tree species, which is planted cropping system. In this particular study, Economical aspects and viability of wheat and Mustard have been studied. Trees intercropped with crops attained better growth and higher litter. In the study of nutrients (NPK) it is reviewed that all the three nutrients increase as the age of trees increases. All the nutrients increases as the tree age are increased. It is clearly seen after the whole research work done, nutrients in the soil are high insole plantation of trees. The yield of intercrops is low in the fields which are cultivated along with trees. The height of intercrops is higher under Poplar than intercrops under Eucalyptus. This might be due to the leaf pattern and its canopy shade. Non-significant results were obtained for tillers per plant and effective tillers per plant in wheat, however, more tillers were found in pure cropping. In Mustard primary branches per plant and seeds per siliqua were at par under Eucalyptus, Poplar, and pure cropping. Yield parameters such as secondary branches per plant, siliqua per plant, and test weight were significantly higher in pure cropping. The grain and straw/stover yields of both the crops under Eucalyptus and Poplar decreased significantly as compared to open fields (crops without Eucalyptus and Poplar).

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