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Effect of fertility levels on mustard (*Brassica juncea*) seed yield, quality and economics under varying poplar (*Populus deltoides*) tree densities

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ABSTRACT

An experiment was conducted during *rabi* of 2008-09 and 2009-10 at Pantnagar, to study the effect of different doses of recommended fertilizers on yield and yield attributes, seed quality, economics and nutrient balance of Indian mustard (*Brassica juncea* L.), under varying poplar (*Populus deltoides* Bartr. Ex. Marsh.) tree densities. Seed yield, oil content and oil yields were not influenced significantly by tree densities in both the years. However, glucosinolate content was improved underneath trees. Maximum benefit: cost ratio from crop was obtained in sole crop with 100% RDF and from agrisilvicultural system (7.81) under 1000 trees/ha density with 50% RDF. With an increase in recommended dose of fertilizer (RDF), seed and stover yields increased significantly upto 100% (1.04 t/ha and 3.41 t/ha) and 125% of RDF (2.03 t/ha and 6.0 t/ha) in 2008-09 and 2009-10, respectively. Oil content decreased but oil yield (340 and 627 kg/ha) and protein content (23.7 and 22.9%) improved significantly upto 100% of RDF in both the years. Similarly, protein yields (245 and 456 kg/ha) and glucosinolate content (80.3 and 87.6 mM/g of seed) increased upto 100 and 125% of RDF in 2008-09 and 2009-10, respectively. A density of 1,000 trees/ha and 100% RDF (120 kg N + 17.4 kg P_2O_5 + 16.6 kg K_2O/ha) was found most suitable and economical for mustard–poplar mixed agrisilvicultural system.

Key words: Economics, Fertility level, Indian mustard, Poplar, Quality, Yield

Poplar based agroforestry system is one of the productive, ecologically sound and socio-economically viable alternate land-use systems in its ecological range (Chauhan *et al.,* 2010). This system has been quite popular in northern states of the country and its area has been expanding every year. The soils under this agrisilvicultural system have improved in organic matter due to recycling of leaf litter, fine roots and twigs of poplar. The fine root system of poplar is generally concentrated in the top 15 cm soil layers (Singh and Singh, 1994) and becomes more competitive with shallow rooted crops like wheat in winter season. Wheat, which is generally intercropped is poplars is more prone to damage by wild animals and birds. Indian mustard, which is pungent in taste, could be less vulnerable than that of wheat and can be taken up with minimum investment. Further, area under rapeseed mustard with declining in the north and intercropping with poplar can help in stabilization of the area under this crop. Besides, rapeseed/mustard requires less input in terms of fertilizers and irrigation water and can also capture untapped resources from deeper soil layers through its deeper root system and hence it could be more economical under resource poor conditions. The tree leaf litter addition by poplar varies with age and densities and, therefore, nutrient requirement for the associated intercrop may also vary. The present study was therefore carried out to find out the optimum dose of fertilizers (NPK) under varying poplar tree densities for mustard in poplar-based mixed agrisilvicultural system.

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MATERIALS AND METHODS

A field experiment was conducted at the Agroforestry Research Centre, Patharchatta of G.B. Pant University of Agriculture and Technology, Pantnagar during *rabi* seasons of 2008-09 and 2009-10. The poplar (G 48) saplings were planted at five meter row distance during February 2000 and 16 trees were maintained in each density (250, 500 and 1,000 trees/ha). The soil of the experimental site was clay loam (0–15 cm) in texture, having range of soil pH (8.0–8.05), organic carbon (0.99–1.77%), available nitrogen (430.1–424.4 kg/ha), available phosphorus (35.3–38.3 kg/ha) and available potassium (401.8–410.3 kg/ha) in 0–45 cm soil layer under treeless (sole crop) to 1,000/ha tree density, respectively. The trees were pruned upto 50% of their height before sowing of the crops. Upland rice and wheat cropping sequence was followed for the last seven years at the site. However, no crop in *kharif* season was taken during 2009. The experiment was laid out in a split plot design with four replications. The treatments consisted of four tree densities viz. sole crop (open), 250, 500 and 1,000 trees/ha as main plot and four fertility levels viz. 50, 75, 100 and 125% of recommended dose of fertilizer (RDF) (120 kg N + 17.4 kg P + 16.6 kg K/ha) for mustard as sub-plot. The NPK fertilizer (12:32:16) and urea (46%) were used for supply of N, P and K. Indian mustard 'Kranti' was inter-cropped on November 7/8 in rows 30 cm apart manually using 5 kg seed/ha. Thinning was done 15–20 days after sowing to maintain plant to plant distance of 10 cm. The crop was harvested at physiological maturity between 23 to 26 March. The oil (Soxhlet method), protein and glucosinolate content (Tetrachloropalladate method), N, P and K content in mustard seed and stover were determined using standard methods. Soil chemical properties viz. pH, Organic carbon (OC) and available N, P and K were determined separately for 0–15, 15–30 and 30–45 cm soil depths using standard methods and either the mean pH and OC or total amount of available NPK values were obtained by summing over the three depths. Nutrient balance in the soil was worked out on the basis of initial and final values of N, P and K, respectively. The net return and benefit: cost ratio were worked out by using prevailing market cost of inputs and outputs. Tree volume and biomass were worked out by following a standard method.

RESULTS AND DISCUSSION

Yield and Yield attributes

The crop yields (seed and stover) were low during 2008-09 (Table 1) because of the fewer (3.3 hrs/day) sunshine hours during reproductive periods compared to 4.9 hrs/day in 2009-10 and severe defoliation due to *Alternaria* blight and aphid infestation. The seed yield was not influenced by tree density in either year, but the stover yield decreased with the increase in tree density upto 500 trees/ha density in 2008-09 primarily due to the litter fall coinciding with seedling emergence, which did not occur in the second year as defoliator attack reduced the litter load. Also the litter from above the emerging/growing seedlings was removed to inter-row spaces. The improved branching, increased number of siliquae and hence seed yield/plant with increased tree density compensated plant population effect and hence the seed yield in 2008-09.

With successive increase in fertility levels, both the seed and stover yields increased significantly upto 100 and 125% of RDF in 2008-09 and 2009-10, respectively (Table 1). This may be attributed to an increase in number of branches and siliquae/plant during both the years and higher 1,000-seed weight in 2008-09. The mean seed yield

Table 1. Yield, yield attributes and harvest index of mustard as influenced by poplar tree density and fertility levels

Treatment	Effective plant population/m^2		Branches/ plant		Siliquae/ plant		Test weight (g)		Seed weight/ plant (g)		Seed yield (t/ha)		Stover yield (t/ha)		Harvest index (%)	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Tree density (trees/ha)																
Sole crop	36	28	4.1	5.5	111	174	3.63	4.01	2.99	6.73	0.91	1.79	3.47	5.46	21.0	24.7
250	31	28	4.5	5.7	132	167	3.76	3.94	3.70	6.48	0.97	1.76	3.08	5.31	24.1	25.0
500	31	28	4.9	5.7	135	160	3.71	3.90	3.82	6.38	0.90	1.62	2.84	4.91	24.3	24.8
1,000	31	26	5.2	5.9	133	174	3.62	4.09	3.89	7.06	0.93	1.71	3.22	5.06	22.5	25.3
SEm±	1	0.9	0.2	0.1	5	5	0.13	0.06	0.09	0.19	0.03	0.01	0.07	0.16	0.6	0.2
CD(P=0.05)	4	NS	0.5	NS	15	NS	NS	NS	0.29	NS	NS	NS	0.02	NS	1.9	NS
Fertility levels (% RDF)																
50	32	28	4.0	4.1	109	122	3.34	3.86	2.95	4.60	0.77	1.36	2.57	4.15	23.3	24.8
75	33	28	4.4	5.5	124	154	3.53	3.96	3.39	6.33	0.88	1.66	3.15	5.08	22.0	24.7
100	32	27	4.7	6.1	136	189	3.80	4.11	3.61	7.30	1.04	1.83	3.41	5.50	23.5	25.0
125	32	26	5.6	7.1	142	209	4.04	4.00	4.44	8.42	1.04	2.03	3.48	6.00	23.2	25.3
SEm±	0.8	0.6	0.1	0.2	3	5	0.08	0.09	0.11	0.18	0.02	0.05	0.11	0.11	0.6	0.3
CD(P=0.05)	NS	2.0	0.3	0.5	7	15	0.23	NS	0.32	0.52	0.07	0.13	0.32	0.32	NS	NS

increase with 125% of RDF was 44.2, 21.1 and 7.3% over 50, 75 and 100% of RDF, respectively. Similar finding has been reported by Singh and Rana (2006).

Seed quality parameters

Oil content and oil yield were not influenced by tree densities (Table 2). However, glucosinolate content in seeds was significantly more under 250 and 1000 trees/ha densities compared to sole crop in 2009-10. Protein content remained unaffected during 2009-10. The protein yield (kg/ha) was not influenced significantly by tree densities in both the years as the seed yield remained unaffected under varying tree densities. The oil content was significantly lower with 125% of RDF compared to 50% of RDF in both the years. The more availability of nitrogen at 125% RDF must have increased the proportion of protein substances in seed by way of the high proportion of photosynthates diverted to protein formation leaving a potential deficiency of carbohydrates for conversion to acetyl co-A for the synthesis of fatty acids. Oil yield increased due to fertilizer application upto 100% RDF in both the years because of increased seed yield. However, unlike the oil content, the protein content increased significantly upto 100% of RDF in both the years and thereby increased protein yield upto 100% of RDF in 2008-09 and upto 125% of RDF in 2009-10. Likewise, glucosinolate content increased significantly upto 100 and 125% of RDF in 2008-09 and 2009-10, respectively. Significant positive association of protein with glucosinolate content occurs (Chauhan *et al.,* 2007).

Table 2. Seed quality parameters and oil and protein yields in mustard as influenced by poplar tree density and fertility levels

Treatment	Oil (%)		Oil yield (kg/ha)		Protein (%)		Protein yield (kg/ha)		Glucosinolate content (μ mole/g seed)	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Tree density (trees/ha)										
Sole crop	32.5	35.0	295	624	23.4	22.5	215	405	73.2	77.8
250	32.8	34.5	319	605	22.5	22.6	219	386	79.5	85.8
500	32.2	34.6	292	554	22.3	22.3	204	350	78.8	81.6
1,000	32.9	33.3	307	570	24.0	22.0	225	371	81.2	87.9
SEm±	0.6	0.8	11	19	0.3	0.6	7	13	1.8	2.0
CD (P=0.05)	NS	NS	NS	NS	1.0	NS	NS	NS	NS	6.4
Fertility levels (% RDF)										
50	34.2	35.9	264	488	22.2	21.7	171	292	74.8	80.5
75	32.5	34.3	286	569	22.4	22.0	196	357	76.8	82.3
100	32.7	34.3	340	627	23.7	22.9	245	409	80.3	82.7
125	31.0	32.9	324	670	24.1	22.9	251	456	80.8	87.6
SEm±	0.6	0.6	10	21	0.2	0.3	6	7	1.3	1.4
CD (P=0.05)	1.7	1.8	31	59	0.7	0.9	16	20	3.7	3.9

Table 3. Available N balance (kg/ha) in soil profile upto 45 cm after two crop seasons as influenced by poplar tree density and fertility levels

Treatment	Initial available N in soil (kg/ha)	Total N applied (kg/ha)	Total N uptake (kg/ha)	Expected balance (kg/ha)	Actual balance (kg/ha)	Net gain or loss (kg/ha)
Tree density (trees/ha)						
Sole crop	430.1	210	151.2	488.9	479.3	-9.6
250	442.8	210	145.5	507.3	508.6	1.3
500	506.9	210	128.9	588.0	487.3	-100.7
1,000	424.4	210	141.1	493.3	491.5	1.8
Fertility levels (% RDF)						
50	451.1	120	109.4	461.7	482.8	21.1
75	451.1	180	132.6	498.5	493.2	-5.3
100	451.1	240	155.0	536.1	492.9	-43.2
125	451.1	300	168.7	582.4	497.8	-84.6

Initial value: (Available N, kg/ha)
Sole crop : 184.5, 128.3, 117.3= 430 .1 kg/ha in 0-15, 15-30 and 30-45 cm soil layers
250 trees/ha : 197.5, 135.3, 110.0=442.8 kg/ha in 0-15, 15-30 and 30-45 cm soil layers
500 trees/ha : 231.8, 173.8, 101.3=506.9 kg/ha in 0-15, 15-30 and 30-45 cm soil layers
1000 trees/ha : 182.3, 134.3, 107.8=424.4 kg/ha in 0-15, 15-30 and 30-45 cm soil layers

Nutrient uptake and available nutrient balance

Maximum N, P and K uptake was recorded in sole crop followed by that under 250 and 1000 trees/ha densities and minimum uptake was recorder under 500 trees/ha density (Table 3-5). Similarly, N, P and K uptake was increased with increasing levels of recommended dose fertilizer and maximum uptake of N, P and K was recorded with 125% RDF. NPK uptake followed a similar trend of seed and stover yield in respective treatments. The available N and P balance was negative in 500 trees/ha density as the fine root biomass was expected to be higher under wider (5 x 4 m) spacing for utilization of mineralized N and P by the tree component of the system (Singh and Singh, 1994). The 1000 trees/ha density resulted in a positive balance of available NPK due to higher litter biomass turnover under this density. The beneficial effect of leaf litter/organic matter on the available K balance could be due to the reactions that change non-exchangeable potassium to exchangeable potassium in the presence of organic matter (Bharadwaj *et al.*, 1994) as the organic matter content had a significant positive correlation (r = 0.0745) with exchangeable potassium.

The maximum positive balance of available N and P was recorded with 50% RDF due to lesser amount of nitrogen and phosphorus uptake by the mustard crops. Contrary to available N and P, the available K balance was positive with the application of increased doses of N, P and K.

Table 4. Available P balance (kg/ha) in soil profile upto 45 cm after two crop seasons as influenced by poplar tree density and fertility levels

Treatment	Initial available P in soil (kg/ha)	Total P applied (kg/ha)	Total P uptake (kg/ha)	Expected balance (kg/ha)	Actual balance (kg/ha)	Net gain or loss (kg/ha)
Tree density (trees/ha)						
Sole crop	35.3	30.6	24.8	41.1	55.5	14.4
250	45.5	30.6	24.5	51.6	54.9	3.3
500	47.6	30.6	22.9	55.3	50.3	-5.0
1000	38.3	30.6	24.4	44.5	57.6	13.1
Fertility levels (% RDF)						
50	41.7	17.4	18.5	40.6	53.6	13.0
75	41.7	26.2	23.4	44.5	55.5	11.0
100	41.7	35.0	26.3	50.4	54.7	4.3
125	41.7	43.6	28.4	56.9	54.5	-2.4

Initial value: (Available P, kg/ha)
Sole crop : 22.0, 8.5, 4.8= 35.3 kg/ha in 0-15, 15-30 and 30-45 cm soil layers
250 trees/ha : 27.0, 10.5, 8.0=45.5 kg/ha in 0-15, 15-30 and 30-45 cm soil layers
500 trees/ha : 27.0, 13.8, 6.8=47.6 kg/ha in 0-15, 15-30 and 30-45 cm soil layers
1000 trees/ha : 22.0, 9.0, 7.3=38.3 kg/ha in 0-15, 15-30 and 30-45 cm soil layers

Table 5. Available K balance (kg/ha) in soil profile upto 45 cm after two crop seasons as influenced by poplar tree density and fertility levels

Treatment	Initial available K in soil (kg/ha)	Total K applied (kg/ha)	Total K uptake (kg/ha)	Expected balance (kg/ha)	Actual balance (kg/ha)	Net gain or loss (kg/ha)
Tree density (trees/ha)						
Sole crop	401.8	29.2	144.1	286.9	435.0	148.1
250	515.3	29.2	141.0	403.5	475.0	71.5
500	437.0	29.2	122.8	343.4	477.1	133.7
1000	410.3	29.2	136.6	302.9	455.0	152.1
Fertility levels (% RDF)						
50	441.1	16.6	102.3	355.4	451.2	95.8
75	441.1	25.0	135.7	330.4	441.2	110.8
100	441.1	33.4	147.6	326.9	478.2	151.3
125	441.1	41.8	159.0	323.9	471.6	147.7

Initial value: (Available K, kg/ha)
Sole crop : 225.8, 104.0, 72.0= 401.8 kg/ha in 0-15, 15-30 and 30-45 cm soil layers
250 trees/ha : 275.3, 145.5, 94.5= 515.3 kg/ha in 0-15, 15-30 and 30-45 cm soil layers
500 trees/ha : 239.0, 125.5, 72.5= 437.0 kg/ha in 0-15, 15-30 and 30-45 cm soil layers
1000 trees/ha : 232.5, 103.3, 74.5=410.3 kg/ha in 0-15, 15-30 and 30-45 cm soil layers

Table 6. Cost of cultivation, net returns and benefit: cost ratio as influenced by poplar tree density and fertility levels (mean data)

Treatment	Cost of cultivation (× 10^3 ₹/ha)			Net returns (× 10^3 ₹/ha)			Benefit : cost ratio		
	Mustard	Poplar	System	Mustard	Poplar	System	Mustard	Poplar	System
D1F1	11.63	0	11.63	8.03	0	8.03	0.69	0	0.69
D1F2	12.25	0	12.25	10.87	0	10.87	0.89	0	0.89
D1F3	12.80	0	12.80	14.69	0	14.69	1.15	0	1.15
D1F4	13.38	0	13.38	15.22	0	15.22	1.14	0	1.14
D2F1	11.63	0.7	12.33	8.54	48.86	57.40	0.73	69.80	4.66
D2F2	12.25	0.7	12.95	12.02	48.86	60.88	0.98	69.80	4.70
D2F3	12.80	0.7	13.50	12.64	48.86	61.50	0.99	69.80	4.56
D2F4	13.38	0.7	14.08	14.00	48.86	62.86	1.05	69.80	4.46
D3F1	11.63	1.4	13.03	5.04	77.87	82.91	0.43	55.62	6.36
D3F2	12.25	1.4	13.65	8.30	77.87	86.17	0.68	55.62	6.31
D3F3	12.80	1.4	14.20	11.30	77.87	89.17	0.88	55.62	6.28
D3F4	13.38	1.4	14.78	12.20	77.87	90.07	0.91	55.62	6.09
D4F1	11.63	1.8	13.43	5.93	98.90	104.83	0.51	54.94	7.81
D4F2	12.25	1.8	14.05	8.78	98.90	107.68	0.72	54.94	7.66
D4F3	12.80	1.8	14.60	11.17	98.90	110.07	0.87	54.94	7.54
D4F4	13.38	1.8	15.18	13.66	98.90	112.56	1.02	54.94	7.42

*Tree output (Mean annual increment):16.5, 26.3 and 33.4 m^3 under 250, 500 and 1000 trees/ha densities, respectively at rotational age of 9th year.

Tree output was estimated based on Poplar wood price @ 350/q at Rudrapur (U.S. Nagar) market and wood biomass was estimated by considering 846 kg/m^3 of fresh poplar wood. D1, D2, D3 and D4 indicates sole crop, 250, 500 and 1000 trees/ha densities and F1, F2, F3 and F4 indicates 50, 75, 100 and 125% of recommended dose of fertilizer, respectively.

Economics

The net returns, in general, from crop reduced with increase in the tree densities (Table 6). The maximum net return (₹15,220/ha) from crop was obtained in sole crop with 125 % RDF, whereas maximum benefit: cost ratio (1.15) was recorded with 100% RDF in sole crop. The maximum tree output in terms of mean annual increment (33.4 m^3/ha), net returns (98,900/ha/year) and benefit: cost ratio (54.94) were recorded under 1,000 trees/ha density. From system perspective, the maximum net return

(1,12,560/ha/year) was obtained under 1000 trees/ha density with 125% RDF whereas maximum benefit: cost ration (7.81) was obtained under 1,000 trees/ha density with 50% RDF. Tree farming under farmland conditions has been reported to be profitable and supplementary to agriculture (Buvaneswaran *et al.,* 2010). This means that the marginal reduction in income from field crops is overwhelmingly met by income from tree products. This is in addition to improvement in soil properties.

Thus it may be concluded that the recommended dose of NPK should be applied in mustard crop even when it is grown in mixed poplar-based agrisilviculture system. The 1,000 trees/ha density was found most economical and beneficial from soil fertility improvement point of view.

REFERENCES

Bharadwaj, V., Bansal, S.K., Maheshori, S.C. and Omanwar, P.K. 1994. Long term effects of continuous rotational cropping and fertilization on crop yields and soil properties-III. Changes in the fractions of N, P and K of the soil. *Journal of the Indian Society of Soil Science* **42**(3): 392–397.

Buvaneswaran, C., Saranvanan, S. and Jayaraj, R.S.C. 2010. Economics of cultivation of important trees in farm lands in Tamilnadu. *Indian Journal of Agroforestry* **12**(1): 53–58.

Chauhan, J.S., Bhadauria, V.P.S., Singh, M., Singh, K.H. and Kumar, A. 2007. Quality characteristics and their interrelationships in Indian rapeseed-mustard (*Brassica* sp.) varieties. *Indian Journal of Agricultural Sciences* **77**(9): 616–620.

Chauhan, S.K., Sharma, S.C., Beri, V., Ritu, Yadav, S. and Gupta, N. 2010. Yield and carbon sequestration potential of wheat (*Triticum aestivum*)-poplar (*Populus deltoides*) based agri-silvicultural system. *Indian Journal of Agricultural Sciences* **80**(2): 129–135.

Singh, T. and Rana, K.S. 2006. Effect of moisture conservation and fertility on Indian mustard (*Brassica juncea*) and lentil (*Lens culinaris*) intercropping system under rainfed conditions. *Indian Journal of Agronomy* **51**(4): 267–270.

Singh, V. and Singh, V. 1994. Root distribution in *Populus deltoides* ‘G-3’ plantation in the arid region of north-western India. *Tropical Ecology* **35**(1): 105–113.