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Effect of weed management on nutrient uptake by wheat and associated weeds under wheat-*Eucalyptus tereticornis* based agroforestry system

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Abstract
A field experiment was conducted during winter season to find out the nutrients uptake and energy utilization by weeds and wheat (*Triticum aestivum* L.) under eucalyptus based agroforestry system in randomized block design with three replications. An experiment was conducted at the farmer field village- Majitha, District- Jabalpur during the Rabi season of 2016-17 and 2017-18. The result revealed that the hand weeding found lower weed dry weight (T9: 2.40 and 0.73qha^{-1}) and higher grain yield and straw yield (T9: 19.75, 18.20 and 46.54, 39.72qha^{-1} both the year, respectively) and weedy check recorded higher total weed dry weight and lower grain yield and straw yield. Similarly, hand weeding found lowest removal of N (T9: 2.78 and 0.77kgha^{-1}), P (T9: 0.37 and 0.09kgha^{-1}) and K (T9: 4.16 and 1.30kgha^{-1}) due to effective control on weeds and the highest nutrient removal of N (T10: 29.30 and 27.63kgha^{-1}), P (T10: 6.48 and 6.06 kg ha^{-1}) and K (T10: 47.44 and 46.24 kg ha^{-1}) was recorded under weedy check during both the year. The maximum energy utilization by grain and straw was found under hand weeding 30 DAS (84.93, 78.25 and 200.14, 170.78 lakh kcal ha^{-1}) and minimum in weedy check (51.79, 46.48 and 147.46, 104.35 lakh kcal ha^{-1}).

Keywords: Weeds, crop, energy, nutrients, herbicides

Introduction
The agroforestry (tree + crop) system is more productive and sustainable than pure cropping. India is the first country in the world has implemented the National Agroforestry Policy in 2014, under its Ministry of Agriculture and Farmers Welfare. Its objective is to expand tree plantation in combination with crops and/or livestock to improve overall productivity, reducing unemployment, generating additional source of income and livelihood support to small landholders. The policy also highlights that agroforestry could be implemented to meet the domestic and industrial requirements of the country for wood and its products. Moreover, in this direction, efforts have been made by the farmers and researchers for introducing promising tree based farming systems across the different states in order to attain sustainability (Verma *et al.*, 2017) [14].

Wheat (*Triticum aestivum* L.) is widely intercropped cereal crop during *rabi* season (November - April) with Eucalyptus, Poplar, and other fast growing tree species in Northern states of India *viz.*, Uttarakhand, Punjab, Haryana, Uttar Pradesh and Bihar, parts of Central and Eastern states such as Madhya Pradesh, Chhattisgarh and West Bengal. Weed infestation is one of the major factor limiting crop productivity. For realizing full genetic yield potential of the crop, the proper weed control is one of the essential management practices. Weeds not only reduce the yield but also make the harvesting operation difficult. The weeds usually grow faster than crop plants and thus, absorb the available nutrients earlier resulting in lack of nutrients for the growth of the crop plants. Mani (1975) [11] pointed out that the competition for the nutrients in general, and nitrogen in particular in most situations was the serious factor in limiting the crop yield. Uncontrolled weeds are reported to cause up to 66% reduction in wheat grain yield (Angiras *et al.*, 2008 and Kumar *et al.*, 2011) [1, 9] or even more depending upon the weed density, type of weed flora and duration of infestation.

Materials and methods
The field experiment was conducted at the farmer field Village- Majitha Block-Shahpura District- Jabalpur (M.P.) for study the effect of herbicidal treatments in relation to NPK removal and energy utilization by weeds and crop.

Wheat crop was intercropped in 4 years old *Eucalyptus tereticornis* trees with distance of 3 m X 1.5 m. The experiment was laid out in Randomized Block Design with ten treatments under three replications. The treatment combinations consisted of 2, 4-D @ 0.5litha^{-1}, Metribuzin @ 0.250Kgha^{-1}, Butachlor @ 1 lit ha^{-1}, Clodinafop-propargyl @ 0.140kgha^{-1}, 2, 4-D @ 0.5litha^{-1} *fb* metribuzin @ 0.250Kgha^{-1}, 2, 4-D @ 0.5litha^{-1} *fb* butachlor @ 1litha^{-1}, Metribuzin @ 0.250Kgha^{-1} *fb* butachlor @ 1litha^{-1}, 2, 4-D @ 0.5litha^{-1} + hand weeding at 30 DAS, Hand Weeding at 30 DAS and Weedy check. Wheat variety LOK-1 was sown with 25cm row spacing at a depth of 4cm from the top of the soil by opening furrows through a Kudal. The weed control treatments and herbicides were applied as post emergent at crop tillering stage i.e. about 30 DAS. The aboveground weed dry matter was also recorded from the above thrown quadrates after cutting weeds from the ground level and then oven dried at 70 ^{0}C and converted to m^2.

Nutrient uptake study

The nitrogen, phosphorus and potassium uptake by weeds and crop was determined at harvest. The weeds were collected, dried, grounded into powder and mixed thoroughly to make a composite sample. The nitrogen was analyzed by Micro-Kjeldahl method (Jackson, 1967) [6], Potash was estimated by Flame-Photometer method as described by Black (1965) [3]. Uptake of nutrients by individual weeds, seeds, crop and straw were worked out by multiplying the percentage of nutrients content in dry matter of weeds, seeds and straw per plot.

The nitrogen uptake (kgha^{-1}) was computed by multiplying per cent nitrogen in plant sample with dry matter obtained per hectare at maturity divided by 100.

$$\text{N uptake (kg ha}^{-1}) = \frac{\text{N conc. (\%) x Wt. of dry matter (kg ha}^{-1})}{100}$$

The phosphorus content in the plant sample was estimated by vanado molybdate phosphorus yellow colour method (Jackson, 1973) [7]. From the results of the chemical analysis, phosphorus uptake was calculated as indicated below.

$$\text{P uptake (kg ha}^{-1}) = \frac{\text{P conc. (\%) x Wt. of dry matter (kg ha}^{-1})}{100}$$

The Potassium content in the plant sample was estimated by flame photometer after making appropriate dilution. From the results of the chemical analysis, potassium uptake was calculated as indicated below.

$$\text{K uptake (kg ha}^{-1}) = \frac{\text{K conc. (\%) x Wt. of dry matter (kg ha}^{-1})}{100}$$

Energy utilization by weeds and crop

The energy utilization by weeds and crop was determined after Leith (1965) [10]. He reported the energy content of 4.35kcal per g weed/straw dry weight and 4.30kcal per gram in seeds. These values were utilized for converting the dry weights into energy content.

Results and discussion

Total weed dry weight (q ha^{-1})

The perusal of data reported that the significantly lower weed dry weight was found under hand weeding at 30 DAS (2.40 and 0.73qha^{-1} during 2016-17 and 2017-18, respectively). Whereas, weedy check recorded significantly higher weed dry weight (18.17 and 17.87qha^{-1} during 2016-17 and 2017-18, respectively). The weed control treatments also reduce the total weed dry weight during both the year. The total weed dry weights are reducing during second year than the first year (Table-1). Similar finding was also reported by Kumar *et al.*, (2011) [9], Chander *et al.* (2014) [4].

Grain yield and Straw yield (q ha^{-1})

Grain straw yields of wheat varied significantly due to weed control treatments (Table 1). The grain and straw yields were minimum under weedy check plots due to poor values of yield attributing traits. But both were increased in plots receiving either herbicidal or mechanical weed control. Post emergence application of clodinafop -propargy @ 0.140kgha^{-1} caused significant improvement in grain and straw yields followed by 2, 4-D @ 0.5litha^{-1} + hand weeding at 30 DAS, metribuzin @ 0.250Kgha^{-1} and 2, 4-D @ 0.5litha^{-1}. However, grain yield and straw yields were further increased application of 2, 4-D @ 0.5litha^{-1} *fb* metribuzin @ 0.250Kgha^{-1} and 2, 4-D @ 0.5litha^{-1} *fb* butachlor @ 1litha^{-1} being higher over weedy check due to better values of yield attributing traits. However, hand weeding treatment surpassed all the herbicidal treatments in terms of grain and straw yields on account of superior values of yield attributing traits (Table-1). The hand weeding produced 33.82 and 33.68% higher grain yield over weedy check during both the year. The findings are in close conformity to the findings of Dhawan *et al.* (2009) [5] and Chander *et al.* (2014) [4].

Nutrient removal by weeds

Nitrogen

The significantly minimum removal of nitrogen was found under hand weeding 30 DAS (T9: 2.78 and 0.77kgha^{-1}) followed by 2, 4-D 0.5litha^{-1} (T1: 4.01 and 4.26kgha^{-1}), 2, 4-D 0.5litha^{-1} *fb* metribuzin 0.250Kgha^{-1} (T5: 5.06 and 4.18kgha^{-1}) and 2, 4-D 0.5litha^{-1} + hand weeding 30 DAS (T8: 5.08 and 4.42kgha^{-1}) which was significantly superior during first year over weedy check (T10: 29.30 and 27.63kgha^{-1}). The rest of the weed control treatments were also found significantly superior over weedy check during both the year (Table 2).

Phosphorus

Weed control practices caused distinct variation on phosphorus removal by weeds during both the years. The manually removal of weeds at 30 DAS caused minimum removal of Phosphorus by weeds (T9: 0.37 and 0.09kgha^{-1}) over weedy check (T10: 6.48 and 6.06kgha^{-1}) (Table 2). Among chemical weed control treatment T5- 2, 4-D 0.5litha^{-1} *fb* metribuzin 0.250Kgha^{-1} followed by T1-2, 4-D 0.5litha^{-1} was found minimum removal of phosphorus than other weed control treatments during both the year under *Eucalyptus tereticornis* based agroforestry system during both the year (Table 2).

Potassium

Weed control practices recorded significant influence on Potassium removal by weeds during both the years. The removal of weeds by hand at 30 DAS reduce the removal of potassium by weeds (T9: 4.16 and 1.30kgha^{-1}) over weedy check (T10: 47.44 and 46.24kgha^{-1}) (Table 2). Among chemical weed control treatment T5- 2, 4-D 0.5litha^{-1} *fb* metribuzin 0.250Kgha^{-1} followed by T1-2, 4-D 0.5litha^{-1} was

found minimum removal of phosphorus than other weed control treatments during both the year under *Eucalyptus tereticornis* based agroforestry system during both the year (Table 2).

Nutrient uptake by crops

Total crop

The significantly higher nitrogen uptake by wheat found under hand wedding 30 DAS (T9: 72.10 and 64.15kgha^{-1}), phosphorus (T9: 31.05 and 27.23kgha^{-1}) and potassium (T9: 77.67 and 67.12kgha^{-1}) over weedy check (T10: 32.05 and 26.42kgha^{-1}), phosphorus (T10: 9.09 and 6.90kgha^{-1}) and potassium (T9: 43.00 and 31.15kgha^{-1}) during both the year. Among chemical weed control treatment T4-Clodinafop-propargyl 0.140kgha^{-1} and T5-2, 4-D 0.5litha^{-1} *fb* butachlor 1 lit ha^{-1} recorded higher nutrient uptake by wheat under *Eucalyptus tereticornis* based agroforestry system during both the year (Table 3). Singh *et al*. (2009) [5], Bharat and Kachroo (2010) [2] and Kumar *et al*. (2010) [8] also concluded that hand weeding twice at 30 and 45 days after sowing in wheat significantly reduced the NPK depletion by weeds over all the weed control treatments the main reason for this was lowest weed biomass under the treatments and significantly higher N, P, K uptake by wheat than herbicidal treatments for higher grain yield and straw yield.

Energy utilized by weeds (lakh kcal ha^{-1})

The data showed that the energy utilization by the weeds was significantly higher in weedy check (79.03 and 74.24 lakh kcal ha^{-1}) over the hand weeding 30 DAS (10.44 and 3.19 lakh kcal ha^{-1}) and rest of the weed control treatment during both the year. The chemical weed control treatment also reduce the energy utilization by weeds. 2, 4-D 0.5litha^{-1} *fb* metribuzin 0.250Kg ha^{-1} followed by 2, 4-D 0.5litha^{-1} reduce the energy utilization by weeds than other chemical weed control treatments under *Eucalyptus tereticornis* based agroforestry system during both the year (Table 4).

Grain and straw

The Statistical analysis of the data revealed that the maximum energy utilization by the grains and straw was found under hand weeding 30 DAS (T9: 84.93, 78.25 and 200.14, 170.78lakh kcal ha^{-1}) over weedy check (T10: 51.79, 46.48 and 147.46, 104.35lakh kcal ha^{-1}) which was significantly minimum energy utilization by the grains and straw than the other weed control treatment during both the year (Table 4). The chemical weed control treatments have increased the energy utilization by grain and straw during both the year under *Eucalyptus tereticornis* based agroforestry system during both the year (Table 2).

Conclusion

The hand weeding produced 33.82 and 33.68% higher grain yield over weedy check during both the year. Among chemical weed control treatment the 2, 4-D @ 0.5litha^{-1} and 2, 4-D @ 0.5litha^{-1} *fb* metribuzin @ 0.250Kgha^{-1} reducing the total weed dry weight, nutrient removal by weeds and energy utilization by weeds than other weed control treatments. The weed control treatments are reducing the total weed dry weight, nutrient removal by weeds and energy utilization by weeds, which increase the nutrient uptake by wheat, energy utilization which resulted higher grain yield and straw yield under *Eucalyptus tereticornis* based agroforestry system.

Table 1: Effect of weed management practices on weed dry weight, grain yield and straw yield (q ha^{-1}) under wheat- *Eucalyptus tereticornis* based Agroforestry system

Treatment		Weed dry weight (q ha^{-1})		Grain yield (q ha^{-1})		Straw yield (q ha^{-1})	
		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
T_1	2, 4-D @ 0.5 lit ha^{-1}	2.19 (4.40)	1.83 (3.92)	16.67	15.17	39.92	31.21
T_2	Metribuzin @ 0.250 Kg ha^{-1}	2.56 (6.07)	2.24 (4.50)	17.04	15.32	40.10	31.85
T_3	Butachlor @ 1 lit ha^{-1}	3.00 (8.52)	2.59 (6.23)	13.97	12.85	35.41	28.94
T_4	Clodinafop-propargyl @ 0.140 kg ha^{-1}	3.01 (8.60)	2.63 (6.40)	17.63	16.18	41.36	34.52
T_5	2, 4-D @ 0.5 lit ha^{-1} *fb* metribuzin @ 0.250 Kg ha^{-1}	2.16 (4.17)	1.94 (3.48)	15.84	15.23	38.82	32.64
T_6	2, 4-D @ 0.5 lit ha^{-1} *fb* butachlor @ 1 lit ha^{-1}	2.76 (7.13)	2.41 (5.29)	15.27	14.17	37.67	31.95
T_7	Metribuzin @ 0.250 Kg ha^{-1} *fb* butachlor @ 1 lit ha^{-1}	3.00 (8.53)	2.67 (6.63)	15.00	13.70	36.50	27.99
T_8	2, 4-D @ 0.5 lit ha^{-1} + hand weeding at 30 DAS	2.17 (4.43)	2.07 (4.00)	17.19	16.04	40.22	30.56
T_9	Hand Weeding at 30 DAS	1.65 (2.40)	1.07 (0.73)	19.75	18.20	46.54	39.72
T_{10}	Weedy check	4.31 (18.17)	4.19 (17.87)	13.07	12.07	34.99	28.67
S EM±		0.18	0.14	0.40	0.54	0.82	1.37
CD(P=0.05)		0.53	0.40	1.17	1.57	2.39	3.99

Table 2: Effect of weed management practices on nutrient (N, P and K) removal by weeds (kg ha^{-1}) under wheat- *Eucalyptus tereticornis* based agroforestry system

Treatment		Nutrient removal by weeds (kg ha^{-1})					
		Nitrogen		Phosphorus		Potassium	
		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
T_1	2, 4-D 0.5 lit ha^{-1}	4.01	4.26	0.94	0.88	9.02	7.67
T_2	Metribuzin 0.250 Kg ha^{-1}	7.60	5.72	1.39	1.03	11.46	8.47
T_3	Butachlor 1 lit ha^{-1}	10.44	7.43	2.21	1.56	16.79	12.34
T_4	Clodinafop-propargyl 0.140 kg ha^{-1}	11.79	8.93	2.00	1.45	16.14	12.10
T_5	2, 4-D 0.5 lit ha^{-1} *fb* metribuzin 0.250 Kg ha^{-1}	5.06	4.18	0.82	0.62	8.09	6.79
T_6	2, 4-D 0.5 lit ha^{-1} *fb* butachlor 1 lit ha^{-1}	9.04	6.36	1.84	1.28	14.50	10.77
T_7	Metribuzin 0.250 Kg ha^{-1} *fb* butachlor 1 lit ha^{-1}	11.19	8.61	2.03	1.51	17.51	13.63
T_8	2, 4-D 0.5 lit ha^{-1} + hand weeding 30 DAS	5.08	4.42	0.80	0.70	7.95	7.25
T_9	Hand Weeding 30 DAS	2.78	0.77	0.37	0.09	4.16	1.30
T_{10}	Weedy check	29.30	27.63	6.48	6.06	47.44	46.24
S EM±		1.25	0.79	0.23	0.19	1.60	1.17
Treatment (T) CD(P=0.05)		3.65	2.30	0.67	0.55	4.66	3.40

Table 3: Effect of different weed management practices on nutrient uptake (N, P and K) by wheat crop kg ha^{-1} at harvest under wheat-*Eucalyptus tereticornis* based agroforestry system

Treatment		Total crop					
		Nitrogen		Phosphorus		Potassium	
		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
T_1	2, 4-D 0.5 lit ha^{-1}	46.57	40.23	17.30	14.20	57.23	45.72
T_2	Metribuzin 0.250 Kg ha^{-1}	49.41	42.43	18.40	15.19	57.64	46.66
T_3	Butachlor 1 lit ha^{-1}	38.42	34.19	13.50	11.41	47.82	39.52
T_4	Clodinafop-propargyl 0.140 kg ha^{-1}	56.56	49.93	20.60	17.75	63.03	53.38
T_5	2, 4-D 0.5 lit ha^{-1} *fb* metribuzin 0.250 Kg ha^{-1}	51.12	46.46	20.30	17.85	57.50	49.30
T_6	2, 4-D 0.5 lit ha^{-1} *fb* butachlor 1 lit ha^{-1}	46.75	41.86	17.22	15.03	54.77	46.88
T_7	Metribuzin 0.250 Kg ha^{-1} *fb* butachlor 1 lit ha^{-1}	42.82	36.63	14.58	11.95	50.07	39.35
T_8	2, 4-D 0.5 lit ha^{-1} + hand weeding 30 DAS	58.18	51.20	24.73	20.56	63.12	50.19
T_9	Hand Weeding 30 DAS	72.10	64.15	31.05	27.23	77.67	67.12
T_{10}	Weedy check	32.05	26.42	9.09	6.90	43.00	31.15
S EM±		1.73	2.12	0.54	0.83	1.86	2.57
Treatment (T) CD (P=0.05)		5.04	6.19	1.56	2.42	5.43	7.51

Table 4: Energy utilized by Weeds, Grain and Straw under wheat- *Eucalyptus tereticornis* based agroforestry system

Treatment		Energy utilized (lakh kcal ha^{-1})					
		by weeds		Grain		Straw	
		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
T_1	2, 4-D 0.5 lit ha^{-1}	19.14	15.95	71.67	65.23	171.64	134.20
T_2	Metribuzin 0.250 Kg ha^{-1}	26.39	19.58	73.10	65.86	172.42	136.96
T_3	Butachlor 1 lit ha^{-1}	37.05	27.12	59.71	55.97	151.69	122.55
T_4	Clodinafop-propargyl 0.140 kg ha^{-1}	37.41	27.84	75.81	69.59	177.86	148.45
T_5	2, 4-D 0.5 lit ha^{-1} *fb* metribuzin 0.250 Kg ha^{-1}	18.13	14.36	68.10	65.50	166.94	140.35
T_6	2, 4-D 0.5 lit ha^{-1} *fb* butachlor 1 lit ha^{-1}	31.03	23.01	65.65	60.92	161.97	137.37
T_7	Metribuzin 0.250 Kg ha^{-1} *fb* butachlor 1 lit ha^{-1}	37.12	28.86	64.50	58.92	156.95	120.37
T_8	2, 4-D 0.5 lit ha^{-1} + hand weeding 30 DAS	19.29	16.82	70.13	68.97	172.93	131.42
T_9	Hand Weeding 30 DAS	10.44	3.19	84.93	78.25	200.14	170.78
T_{10}	Weedy check	79.03	74.24	51.79	46.48	147.46	104.35
S EM±		3.45	2.57	2.18	2.98	3.67	7.78
Treatment (T) CD (P=0.05)		10.06	7.49	6.36	8.70	10.71	22.71

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