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Evaluation of different weed management practices on nutrient uptake, yield and soil microbial population of wheat (*Triticum aestivum* L.)

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Abstract
A field experiment was conducted during *rabi,* season of 2019-20 at the Research farm, Bihar Agricultural College, Sabour, Bhagalpur.The experiment consisting of fourteen treatments was laid out in randomized block design with three replications. The crop was infested with the divergent type of weed flora e.g. *Phalaris minor, Fumaria parviflora* and *Cynodon dactylon* of grassy, *Chenopodium album*, *Anagallis arvensis*, *Melilotus alba*, *Argemona Mexicana* and *Solanum nigrum* of broad-leaved and *Cyperus rotundus, Cyprus iria* and *Cyprus difformis* of sedges group.The sowing of wheat variety HD-2967 was done on 23th November 2019, and harvesting was done on 5th April, 2020. The results revealed that ready-mix application of (clodinafop-propargyl @ 60 g a.i. ha^{-1} + metsulfuron-methyl @ 4 g a.i. ha^{-1} PoE) and(mesosulfuron @ 12 g a.i. ha^{-1} + iodosulfuron-methyl-sodium @ 2.4 g a.i. ha^{-1}PoE) gave higher weed control efficiency (82.02%, 79.31%), lower weed index (4.56%, 6.81%) respectively.Both of these treatments recorded 69.04 and 65.47 per cent grain yield enhancement along with the highest benefit-cost ratio (1.65 and 1.57).The maximum nutrient uptake was also noticed under T_8 and T_{12}. No any phytotoxic symptoms has been recorded under these two treatments.Among nutrient content (%), phosphorus content (%) in grain and straw has been recorded highest in weed free and it was significantly at par with T_4, T_5, T_8 and T_{10} treatment respectively.Based on all the observation recorded, clodinafop-propargyl @ 60 g a.i. ha^{-1} + metsulfuron-methyl @ 4 g a.i. ha^{-1} PoE has performed better in all respects amongst all the herbicide applied treatment followed bymesosulfuron @ 12 g a.i. ha^{-1} + iodosulfuron-methyl-sodium @ 2.4 g a.i. ha^{-1} PoE.The maximum bacterial count (10.55 x 10^{7} CFU g^{-1}soil) was observed under the treatment T_8 while fungi and actinomycetes population were found higher under weedy check.

Keywords: Post-emergence herbicides, weed control efficiency, weed index, benefit-cost ratio

Introduction

Wheat (*Triticum aestivum* L.) is India's second most important cereal crop after rice, and accounts for 31.5% of the country's total food grain basket.Wheat is generally infested by both grassy weeds viz., *Phalaris minor* and *Avena spp.* and broad leaf weeds i.e. *Chenopodium album, Fumaria parviflora, Melilotus indica, Anagalles arvensis, Cirsium arvense, Lathyrus aphaca and Vicia sativa*. Hence, weed control is essential for increasing wheat production. It has been reported that with production of each kilogram of weed, one-kilogram wheat grains are reduced (Chaudhary *et al*., 2008) [2]. Weed infestation is one of the main causes of low wheat yield not only in India but all over the world, as it reduces wheat yield by 37-50% (Waheed *et al*. 2009) [12]. Rice-wheat is one of the most important cropping systems in northern part of the country. The *Phalaris minor* is one of the very serious problems in wheat in this cropping system and sometimes almost 65% crop losses have been reported (Chhokar *et al*. 2008) [5]. Broad-leaved weeds (BLWs) are also causing a threat, but their management is comparatively easier and effective, whereas, control of *Phalaris minor* has become a serious challenge. Chemical weed control is a preferred practice due to scare and costly labour as well as lesser feasibility of mechanical or manual. This crop has competition with several grassy and broad-leaf weeds during its growth period depending upon the adopted agronomic practices, soil types, underground water quality, weed control techniques and cropping system followed. However, due to the continuous use of these herbicides, *P. minor* also evolved resistance against them (Dhawan *et al*. 2009) [6]. Presently, its control has become even more in difficult after it evolved multiple herbicide resistance to recommended herbicides: diclofop-methyl, fenoxaprop-p-ethyl, clodinafop propargyl, pinoxaden (ACCase); sulfosulfuron and pre-mix of mesosulfuron + iodosulfuron (ALS inhibitors); mediated by enhanced metabolism and target site mutations (Dhawan *et al*. 2012) [7]. During surveys and meeting with farmers, it was reported that the herbicide resistance in weeds evolved due to non-following of herbicide rotation, wrong time and method of herbicide application.

If one herbicide stops working, farmers only change the brand, not the group of the herbicides. This indicated the need for intervention of herbicides with different mode of action in the rotation or sequential application for control of complex weed flora in wheat. Tank-mix or pre-mix use of different herbicide chemistries or sequential application of pre and post emergence herbicides at different times showed effective weed control (Baghestani *et al*. 2008) [1]. Keeping all the above facts in view, an attempt was made to find out the efficacy of different herbicides against complex weed flora to improve the productivity of wheat.

Materials and Methods

The experimentwas conducted during *rabi* season of 2019-20 at Research farm of Bihar Agricultural University, Sabour, Bhagalpur (Bihar).Geographically, Bhagalpur is situated at latitude of 25°15' 40" N and longitude 87°2' 42" E with altitude of 45.75 meters above the mean sea level under Gangetic plains of India. The average annual rainfall of this locality is 1167.0 mm, about 75 to 80% of which precipitates during middle of June to middle of October (about 120 days) and there is very scanty rainfall during the remaining period (245 days). Pre-monsoon showers are usually received in the month of May which is the hottest month when average monthly temperature reaches around 36 °C while winter monthly average temperature drops below 10 °C in the month of January. During crop season Nov.2019-April 2020, minimum and maximum temperature ranged between 5.5 °C to 22.6 °C and 17.3 °C to 36.4 °C, respectively. While the mean relative humidity was in the ranges of 84.9% to 97.8% at 7:00 AM and 55% to 82.4% at 2:00 PM respectively. Total rainfall received during the crop growing season was 118.5 mm. The range of average sun shine hour and evaporation were 1.1 hr. to 8.9 hr. and 0.4 mm to 8.5 mm, respectively. Fertility status of the experiment as envisaged through organic C (0.50), available nitrogen (192.45) was low and phosphorus (22.64) and potash (191.88) was in medium range. Fourteen weed management practices viz, T_1: Pendimethalin 30% EC @ 1000g a.i. ha^{-1} + Metribuzin 70%WP @ 210 g a.i. ha^{-1} as PE,T_2: Metribuzin 70% WP @ 210 g a.i. ha^{-1} as PE, T_3: Metribuzin (70% WP) @ 210 g a.i. ha^{-1} as PoE,T_4: Carfentrazone-ethyl 40% DF @20 g a.i. ha^{-1} asPoE, T_5: Metsulfuron-methyl 20% WP @ 4 g a.i. ha^{-1} as PoE, T_6: 2,4-D ethyl ester 38% EC @ 500 mla.i. ha^{-1} as PoE, T_7: Sulfosulfuron 75% WG @ 25 g a.i. ha^{-1} as PoE, T_8: Clodinafop-propargyl 15% + Metsulfuron-methyl 1% WP @ 60+4 g a.i. ha^{-1} as PoE, T_9: Sulfosulfuron 75% + Metsulfuron-methyl 5% WG @ 30+2 g a.i. ha^{-1} as PoE, T_{10}: Carfentrazone-ethyl 20% + Sulfosulfuron 25% WG@ 20+25 g a.i. ha^{-1} as PoE, T_{11}: Clodinafop-propargyl 15% WP + Metribuzin 70% WP @ 60+175 g a.i. ha^{-1} as PoE,T_{12}: Mesosulfuron-methyl 3% + Iodosulfuron-methyl-sodium 0.6% WG@ 12+2.4 g a.i. ha^{-1} as PoE, T_{13}: Weed free and T_{14}: Weedy checkrespectively in a randomized block design (RBD) with three replications. The size of the experimental plot was 16.24 m^{-2}. The wheat variety 'HD-2967' were sown in row to row spacing of 20 cm, on November 23, 2019, using seed-rate @ 125 kg ha^{-1}. Urea, DAP, muriate of potash and were used to supply 150 kg N, 60 kg P_2O_5 and 40 kg K_2O respectively. Half dose of nitrogen and full dose of phosphorus potassium were applied as basal dressing in the field at the time of sowing. Remaining half dose of nitrogen through urea was top-dressed after first irrigation. The herbicides were sprayed with the help of a hand-operated Knapsack sprayer fitted with flat fan nozzle using 500 liters of water ha^{-1}. Microbial count was determined by the technique of Standard Pour Plate using soil extract *agar*, Rose Bengal *agar* and Ken Knight's *agar* medium, respectively as described by Rangaswami and Bagyaraj 1993. Serial dilutions of the suspension were prepared with sterile water and placed in suitable media and population of each microbial group was expressed as a number of cells $colonies^{-1}$ forming units (CFU) per g of soil. The enumeration of the microbial population was done by dilution plate technique. The plates were incubated at 28±5 °C. The counts were taken at 5^{th} and 7^{th} day of incubation. The results were reported as a number of cells per gram of soil as an average of triplicates. Nitrogen conent were estimated by using micro-kjeldahl distillation method, phosphorus by vanado-molybdo-phosphoric acid yellow colour method, potassium by flame photometer method.

Results and Discussion

Effect on soil microbial population, grain yield,WCE and economics of wheat

There was no significant difference among the various herbicidal treatments. However, the maximum bacterial count (10.55 x 10^7 CFU g^{-1}soil) was observed under the treatment T_8 and minimum bacterial count was found under the treatment T4 (7.19 x 10^7 CFU g^{-1}soil) (Table 1). The maximum actinomycetes count (17.45 x 10^6 CFU g^{-1} soil) was observed under the treatment T14 and the minimum actinomycetes count was observed under the treatment T10 (14.84 x 10^6 CFU g^{-1} soil). Fungi count (14.84 x 10^4 CFU g^{-1} soil) were also higher under the T14 and the minimum fungi count was observed under the treatment T1 (12.26 x 10^4 CFU g^{-1} soil).The microbial population decreased to the significant level on the day of application of herbicides and at 30 DAS. Thereafter microbe's population increased in plots receiving treatment. The main reason behind this is improvement of organic carbon by incorporation and decomposition process of weeds. However, at initial and harvest stages, microbial population did not vary significantly in all the doses of the pendimethalin, carfentrazone-ethyl, metsulfuron-methyl, sulfosulfuron *etc.* due to some effect of their phytotoxicity. After herbicide application, microbial count varied for a short span of time. Microbes utilize the herbicides and dead weeds as a source of carbon required in metabolism. For the time being, microbes degrade the herbicides and carbon released from degraded herbicide results in an increase of the soil micro flora population (Saini *et al*. 2009) [10]. Grain yield of wheat is affected by accumulation and partitioning of dry matter content in several parts of the plant mainly in the reproductive parts of the crop and yield attributes. Yield benefit due to various weed control treatments over weedy check is largely attributed to better yield attributes, reduced weed density and weed dry matter with higher weed control efficiency. The minimized weed crop competition throughout the growth phase of the crop enabled the crop for availing efficient utilization of available resources i.e. nutrients, light, moisture, and space that had much positive influence on growth, development and yield of wheat. These results might be corroborated with the results of Malik *et al*. (2013). The weed free treatment recorded significantly higher grain yield (4.49 t ha^{-1}) among all the treatments which was at par with T8, T12, and T9 (Table 1). The treatment weedy check produced significantly lower grain yield of (2.52 t ha^{-1}) compared to rest of the treatments. Among all the herbicide applied treatments, significantly higher grain yield of (4.26 t ha^{-1}) was produced with application of clodinafop-propargyl @ 60 g *a.i.* ha^{-1}+ metsulfuron-methyl @ 4 g *a.i.* ha^{-1}(T_8)

which was at par (4.17 t ha^{-1}) with mesosulfuron @ 12 g a.i. ha^{-1} + iodosulfuron-methyl-sodium @ 2.4 g a.i. ha^{-1}(T_{12}) and (3.93) sulfosulfuron @ 30 g a.i. ha^{-1}+ metsulfuron-methyl @ 2 g a.i. ha^{-1} (T_9).The increased grain yield in these treatments is because of lowest weed density & higher WCE along with better yield attributes like number of spikes per m^2, number of grains per spike and test grain weight (Punia *et al*. 2017). All the herbicide applied treatments had better WCE. The maximum WCE was obtained (82.02%) under T_8 (clodinafop-propargyl @ 60 g *a.i.* ha^{-1} + metsulfuron-methyl @ 4 g *a.i.* ha^{-1} PoE) treatment at 60 days after sowing and minimum weed control efficiency (44.23%) was recorded in the treatment T2 (metribuzin @ 210 g a.i. ha^{-1} PE) (Table 1). The reducing trend of WCE is because of decreasing weed dry matter with advancement of time (Choudhary *et al*. 2016) [4]. Different weed control treatments were found to have significant effect on benefit: cost (B:C) ratio (Table 1). The highest B:C ratio observed without marked difference in T_8 (1.65, T_9 (1.45), T_{10} (1.32), T_{12} (1.57) and T_{13}(1.48) was mainly due to higher economic yield and net returns in these treatments.The lowest B:C ratio (0.65) was observed in T_{14} (weedy check) (Meena *et al*. 2019) [8].

Effect onnutrientcontent and uptake by grain and straw in wheat

The Nutrient uptake by crop is primarily a function of yield and nutrient content.The maximum nitrogen uptake (109.41 kg ha^{-1}) was recorded under the treatment T13 (weed free) and it has been significantly superior to all the other treatments except T_8 treatment (Clodinafop-propargyl + Metsulfuron-methyl) (Table 2). The minimum nitrogen uptake (45.89 kg ha^{-1}) was recorded under treatment T_{14} (weedy check). Among the all herbicidal treatments, the maximum nitrogen uptake (102.10 kg ha^{-1}) was noticed under T8. The maximum phosphorus (37.20 kg ha^{-1}) in plants was recorded under the treatment T13 (weed free) which was significantly superior to all treatments except T_8 (Clodinafop-propargyl + Metsulfuron-methyl) and minimum phosphorus uptake (11.45 kg ha^{-1}) was noticed under treatment T_{14} (weedy check). Among herbicides treatments, maximum phosphorus uptake (34.54 kg ha^{-1}) was noticed under the treatments $T_{8.}$ The maximum potassium (122.12 kg ha^{-1}) in plants was recorded under the treatment T13 (weed free) which was at par with all other treatments except T_8 (Clodinafop-propargyl + Metsulfuron-methyl) and minimum potassium uptake (52.72 kg ha^{-1}) was recorded under treatment T_{14} (weedy check). Among all herbicidal treatments, maximum potassium uptake (113.75 kg ha^{-1}) by plants was recorded under the treatment T_8(Tomar and Tomar 2014).All the weed control measures tended to improve the nitrogen, phosphorus and potassiumuptake by grain and straw as compared to weedy check. There was no significant effect of application of various herbicides on nitrogen and potassium content (%) of wheat. However, weed free plot (0.56) recorded higher phosphorus content (%) in wheat grain and straw and was at par with T_4, T_5, T_8 and T_{10} treatments respectively. This could be due to conversion of phosphorus from unavailable form to available form by the action of microbes in soil. These results may be corroborated with the results of (Choudhary *et al*. 2017) [3]. The high uptake of nutrients is because of less crop weed competition along with higher nutrient absorption which has led to higher N, P and K content in grain and straw.

Table 1: Effect of different weed management practices onsoil microbial population, grain yield,WCE and economics of wheat

Treatments		Dose (g/ml a.i. ha^{-1})	Bacteria (CFU×10^7 g^{-1} soil)	Actinomycetes (CFU×10^6 g^{-1} soil)	Fungi (CFU×10^4 g^{-1} soil)	Grain yield (t/ha)	WCE (%) at 60 DAS	B:C ratio
T_1	Pendimethalin + Metribuzin (TM)	1000 + 210	8.75	16.54	12.26	3.19	52.86	0.95
T_2	Metribuzin	210	9.23	17.08	13.60	2.95	44.23	0.86
T_3	Metribuzin	210	8.53	15.16	14.48	2.87	52.98	0.81
T_4	Carfentrazone-ethyl	20	7.19	15.42	13.66	3.38	58.82	1.13
T_5	Metsulfuron-methyl	4	6.54	15.53	14.48	3.43	61.87	1.19
T_6	2,4-D Ethyl Ester	500	8.70	13.84	13.57	3.32	56.83	1.11
T_7	Sulfosulfuron	25	9.21	16.81	12.81	3.58	66.97	1.23
T_8	Clodinafop-propargyl + Metsulfuron-methyl (RM)	60 + 4	10.55	17.13	14.77	4.26	82.02	1.65
T_9	Sulfosulfuron + Metsulfuron-methyl (RM)	30 + 2	9.24	14.92	13.89	3.93	74.08	1.45
T_{10}	Carfentrazone-ethyl + Sulfosulfuron (RM)	20 + 25	8.71	14.84	13.74	3.75	71.01	1.32
T_{11}	Clodinafop-propargyl + Metribuzin (TM)	60 + 175	9.55	15.48	12.41	3.61	68.56	1.22
T_{12}	Mesosulfuron + Iodosulfuron-methyl-sodium (RM)	12 + 2.4	9.34	17.09	14.08	4.17	79.31	1.57
T_{13}	Weed free	-	8.13	17.22	14.41	4.49	100.00	1.48
T_{14}	Weedy check	-	9.55	17.45	14.84	2.52	0.00	0.65
S.Em. ±			0.83	1.31	1.13	2.76	1.29	0.13
CD (P=0.05)			NS	NS	NS	8.02	3.74	0.39
Note: All the herbicides were applied as post emergence (PoE) at 32 DAS except T_1& T_2 i.e. pre-emergence (PE) at 1 DAS.								

Table 2: Effect of different weed management practices on nutrient uptake by grain and straw in wheat

Treatment		Dose (g/ml a.i. ha^{-1})	Nitrogen kg ha^{-1}			Phosphorous kg ha^{-1}			Potassium kg ha^{-1}		
			Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1	Pendimethalin + Metribuzin (TM)	1000 + 210	55.20	15.40	70.60	14.65	6.96	21.62	11.13	67.44	78.57
T_2	Metribuzin	210	51.65	14.51	66.16	13.00	6.21	19.21	9.65	58.67	68.31
T_3	Metribuzin	210	49.32	13.73	63.05	13.37	6.36	19.73	9.58	58.02	67.60
T_4	Carfentrazone-ethyl	20	59.14	16.46	75.60	16.52	7.82	24.34	12.13	73.12	85.26
T_5	Metsulfuron-methyl	4	61.38	17.34	78.72	18.00	8.58	26.58	11.39	69.25	80.65
T_6	2,4-D Ethyl Ester	500	61.25	17.41	78.66	15.11	7.19	22.30	10.11	61.33	71.44
T_7	Sulfosulfuron	25	62.87	17.66	80.52	16.59	7.91	24.51	13.04	79.21	92.24
T_8	Clodinafop-propargyl + Metsulfuron-methyl (RM)	60 + 4	79.51	22.59	102.10	23.43	11.11	34.54	16.15	97.60	113.75
T_9	Sulfosulfuron + Metsulfuron-methyl (RM)	30 + 2	69.46	19.50	88.96	17.63	8.39	26.02	13.63	82.57	96.20
T_{10}	Carfentrazone-ethyl + Sulfosulfuron (RM)	20 + 25	67.42	19.12	86.54	19.26	9.21	28.47	13.36	81.41	94.76
T_{11}	Clodinafop-propargyl + Metribuzin (TM)	60 + 175	59.11	16.20	75.32	15.67	7.45	23.12	11.44	69.28	80.72
T_{12}	Mesosulfuron + Iodosulfuron-methyl-sodium (RM)	12 + 2.4	66.88	18.16	85.05	14.27	6.76	21.03	15.04	90.89	105.93
T_{13}	Weed free	-	85.11	24.30	109.41	24.90	12.31	37.20	17.34	104.78	122.12
T_{14}	Weedy check	-	36.28	9.61	45.89	7.73	3.72	11.45	7.41	45.31	52.72
S.Em. ±			4.38	1.38	5.74	1.60	0.79	2.39	0.99	6.06	7.05
CD (P =0.05)			12.73	4.02	16.69	4.66	2.30	6.95	2.89	17.62	20.51

Note: All the herbicides were applied as post emergence (PoE) at 32 DAS except T_1& T_2 i.e. pre-emergence (PE) at 1 DAS.

Conclusion

Application of clodinafop-propargyl @ 60 g a.i. ha^{-1} + metsulfuron-methyl @ 4 g a.i. ha^{-1} PoEat 32 DAS was the best herbicide combination and can be recommended for wheat in enhancing grain yield in terms of better nutrient uptake, high weed control efficiency, more bacterial growth and ultimately resulting in higher benefit cost ratio.

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