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Research Paper

Effect of crop-establishment methods and weed management on nutrient uptake microbial population and productivity of wheat (*Triticum aestivum*)

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ABSTRACT

A field experiment was conducted at Bikaner, Rajasthan, during the winter (*rabi*) seasons of 2016–17 and 2017–18, to find out the efficacy of crop establishment and weed-management on weed, the yield of wheat (*Triticum aestivum* L.) and its residual effect on succeeding summer greengram [*Vigna radiate* (L.) R. Wilczek]. The treatments in wheat during the winter seasons, comprising 28 combinations having 4 crop-establishment methods and 7 weed- management options, was laid out in a strip-plot design with 4 replications. Wheat variety 'Raj 3077' was sown at 22.5-cm-row spacing using a seed rate of 100 kg/ha. Both stale seedbed and deep tillage methods reduced the density and dry matter of all most weeds at all the stages significantly in comparison to conventional tillage, while stale seedbed using glyphosate at 2.0 kg/ha proved itself best among all the treatments. Metsulfuron @ 4.0 g/ha + 1 hand-hoeing significantly decreased the weed density and dry matter of all the weeds except nut grass (*Cyperus rotundus* L.) and *Burmuda grass* [*Cynodon dactylon* (L.) Pers.] over all herbicidal treatments. The yield of wheat was significantly higher under state seedbed using glyphosate at 2.0 kg/ha followed by stale seedbed SSB using shallow tillage over deep and conventional tillage. In weed management, metsulfuron @ 4.0 g/ha + 1 hand-hoeing significantly increased the yield over other herbicidal treatments. Stale seedbed technique was significant superior in nutrient uptake by grain and straw to deep and conventional tillage. In weed management, metsulfuron 4.0 g/ha + 1 hand-weeding given better response over remained applied treatment. The crop-establishment methods had not significant effect on fungi, bacteria and dehydrogenase activity. In weed-management treatment lowest microbial population were recorded under metsulfuron-treated plot at 7 days after application, whereas at 30 days after application and harvest stage had not significant variation.

Key word : Stale seedbed, Tillage, Metsulfuron, 2, 4-D, Weeds, Wheat

INTRODUCTION

Wheat is one of the most important staple foodgrain crops. Infestation of weeds both annual and perennial is one of the important constraints in the low productivity of wheat in the state. It competes with crops for water, soil, nutrients, light, and space and thus reduces crop yields (Das, 2008). Verma *et al*. (2008) reported infestation of weed throughout crop-growth period caused 43.63% reduction in grain yield of wheat. Stale seed-bed technique involves the soil preparation of a seed-bed to promote germination of weeds, a number of days or weeks before the actual sowing or planting of the crop, thus depleting the seed bank in the surface layer of soil and reducing subsequent emergence of weeds (Rao *et al.,* 2007). Looking to the scenario of stale seed-bed technique with tillage and herbicides and its impact on weed and growth, yield attributes and productivity of wheat, there is a need to test this current practice in wheat. Deep tillage may also bury the weed seed deeper in the soil layer and minimize the weed seed in upper layer of soil. Herbicides play an important role for weed control in close spaced crops like wheat, where manual or mechanical weeding is difficult. Also the mimicry weeds can hardly be weeded out by hand-weeding or other mechanical methods. Chemical weed control is the most suitable option to overcome this problem.

MATERIALS AND METHODS

A field study was conducted during the winter (*rabi*) season of 2016–17 to 2017–18 at Instructional Farm, Swami Keshwanand Rajasthan Agricultural University, Bikaner. The treatments comprising 28 combinations having 4 crop-establishment method (stale seed-bed using shallow tillage, stale seed-bed using glyphosate 2.0 kg/ha,

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deep tillage and conventional tillage) and 7 weed management treatments [weedy check, weed-free, 1 hand-weeding at 30 days after sowing (DAS), 2, 4-D 0.5 kg/ha 30 DAS, metsulfuron 4.0 g/ha , 2, 4-D 0.5 kg/ha 30 DAS + 1 hand-weeding and metsulfuron 4.0 g/ha + 1 hand-weeding were laid out in a strip-plot design with 4 replications. Wheat variety 'Raj 3077' was sown at 22.5-cm-row spacing using seed rate of 100 kg/ha. The soil of experiment site was loamy sand, having 0.08% organic carbon, 8.3 *p*H, and 78, 22 and 210 kg/ha available N, P and K, respectively. Fertilizer was applied as recommended dose in this zone, IC hyper arid partially irrigated (100 kg N + 60 kg P + 40 Kg/ha). In stale seed-bed technique, after seed-bed preparation, the field is irrigated and left unsown to allow weeds to germinate which are killed by a glyphosate or by carrying out shallow tillage prior to the sowing. However, in deep tillage disc plough and in conventional tillage 1 harrow along with cultivator used. Metsulfuron (4 g/ha) and 2, 4-D (0.5 kg/ha) were applied as post-emergence with 500 litres water with the help of knap-sack sprayer, fitted with flat-fan nozzle at 30 DAS. Dry-matter of weed was recorded at 30, 60 DAS and harvesting stage from 0.25/m^2 area by placing a quadrate of 0.5 m × 0.5 m randomly at 3 places in each plot. The weeds were dried in an oven till a constant weight is observed and then transformed into g/m^2 by using the appropriate formula. The data on total weed count and weed dry matter were subjected to square-root transformation to normalize their distribution (Gomez and Gomez, 1984). Weed index is a derived parameter from the crop yields obtained across the treatments of weed control, (Gill and Kumar, 1969).

In order to test the significance of variance in experiments, the data obtained for various treatment effects were analysed statistically as per procedure described by Panse and Sukhatme (1985). The critical differences were calculated to assess the significance of treatment means wherever, the 'F' test was found significant at 5% level of significance.

The enumeration of the total bacteria in soil samples was accomplished by following Serial dilution plate technique (Martin, 1950) using nutrient agar medium for bacterial and potato-dextrose agar (PDA) medium for fungi. The population of microbes was examined in various treatments and expressed as CFU/ml. Dehydrogenase activity was determined using the reduction of 2, 3, 5-triphenyl tetrazolium chloride (TTC) method (Thalmann, 1968).

The nitrogen uptake (kg/ha) was computed by multiplying per cent nitrogen in weed sample with dry matter obtained per hectare at maturity divided by 100.

$$\text{Nitrogen uptake (kg/ha)} = \frac{\text{N conc. (\%)} \times \text{weight of dry-matter of weeds (kg/ha)}}{100}$$

The nitrogen content in the weed sample was estimated by the modified Micro kjeldahl method (Jackson, 1973)

$$\text{Phosphorus uptake (kg/ha)} = \frac{\text{P conc. (\%)} \times \text{weight of dry-matter of weeds (kg/ha)}}{100}$$

The phosphorus content in the weed sample was estimated by vanado molybdateoposphoric yellow colour method (Jackson, 1973). The phosphorus uptake was calculated as:

The potassium content in the weed sample was estimated by flame photometer after making appropriate dilution (Jackson, 1973). The potassium uptake was calculated as:

$$\text{Potassium uptake (kg/ha)} = \frac{\text{K conc.(\%)} \times \text{weight of dry-matter of weeds (kg/ha)}}{100}$$

RESULTS AND DISCUSSION

Crop establishment method

Stale seedbed (SSB) using glyphosate @ 2.0 kg/ha treatment significantly decreased the dry matter of lamb's quarters (*Chenopodium album* L.), *toothed dock* (*Rumex dentatus* L.), nut grass (*Cyperus rotundus*) and bermuda grass (*Cynodon dactylon*) at 30, 60 DAS and at harvesting and, followed by SSB using shallow tillage and it was significantly superior to deep and conventional tillage (Tables 1, 2). The detrimental effect of SSB on dry matter might be due to the removal of most of germinated sprout seeds, which were active in upper top layer soil, without disturbing the soil in comparison to deep and conventional tillage. The perennial weeds, i.e *Cyperus rotundus* and *Cynodon dactylon*, were difficult to control because of its re-germination capacity but with the adoption of stale seed-bed technique particularly using glyphosate at 2.0 kg/ha significantly controlled these weeds. This might be due to fact that glyphosate destroyed reserve food material in its rhizome by its systemic action (Kumar *et al.,* 2015). SSB with shallow tillage was significantly better than conventional practices as minimum soil was disturbed in this technique and led to poor germination of weeds along with wheat crop. These results confirm the finding of Riemens *et al.* (2007) and Kumar and Ladha (2011).

The crop-establishment treatment had no significant effect on population of fungi, bacteria and dehydrogenases activity (Table 1). A recovery in microbial biomass carbon is observed which may be due to the adaptability of the microorganisms in utilizing these herbicides as a source of carbon, resulting in increasing microbial population. Vischetti *et al*. (2002) and Sukul (2006) also reported the initial decrease and recovery with time in microbial biomass carbon with herbicide and fungicide application.

Table 1. Effect of crop establishment and weed management on weed dry-matter (g/m^2) in wheat on pooled basis

Treatment	*Chenopodium album*			*Rumex dentatus*			*Cyperus rotundus*			*Cynodon dactylon*			Total Dry-matter		
	30 DAS	60 DAS	At harvesting	30 DAS	60 DAS	At harvesting	30 DAS	60 DAS	At harvesting	30 DAS	60 DAS	At harvesting	30 DAS	60 DAS	At harvesting
Crop-establishment method															
SSB using shallow tillage	1.45 (1.70)	3.36 (21.97)	7.08 (93.97)	2.02 (3.90)	3.20 (21.12)	8.60 (131.4)	1.51 (1.91)	2.66 (9.90)	2.51 (8.31)	1.53 (1.97)	3.25 (12.18)	7.27 (89.48)	3.01 (9.47)	6.38 (65.34)	13.79 (322.8)
SSB using glyphosate at 2.0 kg/ha	1.37 (1.46)	3.03 (17.31)	6.48 (78.90)	1.84 (3.13)	2.85 (15.55)	8.19 (122.3)	1.24 (1.08)	2.10 (5.71)	2.01 (4.85)	1.07 (0.67)	2.47 (6.49)	6.03 (59.16)	2.51 (6.34)	5.31 (45.06)	12.39 (265.2)
Deep tillage	1.62 (2.27)	3.84 (20.49)	7.62 (108.53)	2.28 (5.17)	3.55 (25.80)	9.50 (156.6)	1.74 (2.70)	2.88 (11.75)	2.71 (9.69)	1.61 (2.23)	3.32 (12.77)	7.99 (106.61)	3.41 (12.36)	7.03 (79.74)	15.04 (381.4)
Conventional tillage	1.70 (2.55)	4.05 (32.21)	8.22 (122.53)	2.72 (7.63)	3.84 (32.10)	9.88 (169.5)	1.82 (3.02)	2.89 (11.82)	2.81 (10.58)	1.69 (2.52)	3.57 (14.94)	8.65 (126.83)	3.82 (15.71)	7.44 (92.02)	15.95 (429.6)
SEm±	0.01	0.05	0.08	0.02	0.06	0.05	0.01	0.03	0.02	0.01	0.03	0.11	0.02	0.12	0.15
CD (P=0.05)	0.03	0.14	0.25	0.06	0.17	0.15	0.04	0.09	0.06	0.03	0.09	0.32	0.07	0.35	0.45
Weed management															
Weedy check	1.67 (2.32)	11.37 (131.9)	21.70 (476.5)	2.51 (6.00)	10.47 (112.38)	24.83 (623.8)	1.72 (2.55)	4.56 (20.69)	4.17 (17.23)	1.61 (2.18)	4.57 (21.03)	15.09 (233.4)	3.63 (13.04)	16.71 (288.0)	36.56 351.0)
Weed free	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 ()	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
1 hand-hoeing at 30 DAS	1.69 (2.41)	4.47 (19.93)	8.12 (66.42)	2.49 (5.91)	1.45 (1.60)	10.24 (107.6)	1.72 (2.54)	2.75 (7.55)	2.61 (6.75)	1.59 (2.10)	2.92 (8.18)	5.71 (32.79)	3.62 (12.96)	6.08 (37.26)	14.48 (213.5)
2, 4-D at 0.5 kg/ha 30 DAS	1.67 (2.31)	4.04 (16.20)	11.31 (128.8)	2.41 (5.53)	6.47 (42.71)	14.51 (212.9)	1.73 (2.55)	4.53 (20.36)	4.14 (16.96)	1.60 (2.16)	4.54 (20.74)	14.05 (202.4)	3.56 (12.55)	9.90 (99.91)	23.53 (561.1)
Metsulfuron at 4.0 g/ha 30 DAS	1.66 (2.27)	2.98 (8.63)	4.99 (25.25)	2.46 (5.73)	3.03 (8.81)	7.27 (53.85)	1.71 (2.51)	4.48 (19.95)	4.13 (16.88)	1.60 (2.16)	4.50 (20.32)	13.91 (196.8)	3.58 (12.66)	7.55 (57.71)	16.97 (293.0)
2, 4-D at 0.5 kg/ha 30 DAS + 1 hand-hoeing at 45 DAS	1.67 (2.32)	0.71 (0.00)	2.47 (5.69)	2.44 (5.57)	0.71 (0.00)	2.98 (8.50)	1.72 (2.54)	0.71 (0.00)	0.89 (0.30)	1.60 (2.15)	2.50 (5.83)	1.49 (1.77)	3.58 (12.58)	2.50 (5.83)	4.08 (16.27)
Metsulfuron at 4.0 g/ha 30 DAS + 1 hand-hoeing at 45 DAS	1.68 (2.33)	0.71 (0.00)	2.17 (4.26)	2.50 (5.96)	0.71 (0.00)	2.75 (7.16)	1.72 (2.56)	0.71 (0.00)	0.94 (0.39)	1.61 (2.18)	2.35 (5.05)	1.42 (1.56)	3.63 (13.02)	2.35 (5.05)	3.71 (13.36)
SEm±	0.01	0.09	0.08	0.03	0.08	0.06	0.01	0.03	0.03	0.01	0.05	0.11	0.03	0.21	0.15
CD (P=0.05)	0.04	0.26	0.24	0.08	0.24	0.17	0.04	0.10	0.08	0.04	0.16	0.33	0.08	0.60	0.44

SSB, Stale seed-bed; DAS, days after sowing; Transformed to $\sqrt{X+0.5}$, **original values

The uptake of nitrogen, phosphorus and potassium by weed with the application of SSB using glyphosate at 2.0 kg/ha was significantly lower than all the other crop-establishment and followed by SSB using shallow tillage. Deep tillage resulted in the statistically lower nitrogen, phosphorus and potassium uptake by weeds compared with conventional tillage. The increase in nitrogen uptake by weeds with the conventional tillage was 62.22, 65.01 and 55.65% over the stale seed-bed using glyphosate at 2.0 kg/ha respectively. These findings are in conformity with those reported by Jain *et al*. (2007) and Kumar *et al.* (2015).

The uptake of N, P and K by grain and straw was significantly higher in SSB treatments because yields were significantly higher in SSB using glyphosate at 2.0 kg/ha/ shallow tillage. This might be owing to the fact that nutrient uptake is a function of yield and nutrient content. Kumar *et al*. (2015) also reported that, higher yield leads to higher uptake of nutrients.

The treatments of stale seed-bed using glyphosate at 2.0 kg/ha accumulated the maximum dry-matter over all the treatments at harvesting. At the time of harvesting, the increase of dry-matter due to adoption of stale seed-bed using glyphosate at 2.0 kg/ha was 14.13 and 11.30% over the deep and conventional tillage, respectively. Stale seed-bed using glyphosate at 2.0 kg/ha significantly increased the growth characters, particularly of dry-matter accumulation, as this technique provides adequate weed control by reducing density and dry-matter particularly of broad-leaf weeds infested the wheat. Our results confirm the findings of Johnson and Mullinix (1995) and Khatun *et al*. (2016).

Stale seedbed using glyphosate at 2.0 kg/ha resulted in significantly higher effective tillers than deep and conventional tillage, but statistically at par with stale seed-bed using shallow tillage; may be owing to better weed control, comparatively higher growth which leads to higher yield-attributing characters of wheat in these treatments as compared to the other treatments. Data showed that spike length, grain/spike and test weight of wheat were not influenced due to different crop-establishment treatments, might be due to different crop-establishment methods and this may be due to the higher number of effective tillers that leads to the dilution effect. Stale seed-bed using glyphosate at 2 kg/ha resulted in significantly higher grain and biological yields than deep and conventional tillage, but statistically at par with stale seed-bed using shallow tillage. The increase of grain yield owing to adoption of SSB using glyphosate at 2.0 kg/ha was 9.98, and 7.74% than deep and conventional tillage, respectively. The favourable effect of conjunctive use of SSB using glyphosate at 2.0 kg/ha on seed yield was owing to significant improvement in dry-matter accumulation and higher number of effective tiller/ m row length were also owing to less competition by weeds for nutrient uptake to wheat. These results are in agreement with the findings of Kumar *et al.* (2015) and Khatun *et al*. (2016).

The SSB using glyphosate at 2.0 kg/ha resulted in significantly higher grain, straw and biological yields than deep and conventional tillage but statistically at par with

Table 2. Effect of crop establishment and weed management on growth, yield attributes and yield on pooled basis

Treatment	Dry-matter (g/mrl) at harvesting	Effective tillers/m row length	Spike length (cm)	Grain/ spike	Test weight (g)	Seed yield (kg/ha)	Straw yield (kg/ha)
Crop-establishment method							
SSB using shallow tillage	148.88	98.18	6.16	35.13	41.11	2967	3907
SSB using glyphosate at 2.0 kg/ha	153.11	101.77	6.20	35.68	41.41	3130	4062
Deep tillage	144.64	93.61	6.13	33.54	41.11	2877	3733
Conventional tillage	140.80	91.45	6.10	33.73	40.63	2808	3621
SEm±	0.81	1.23	0.03	0.62	0.36	44	54
CD (P=0.05)	2.39	3.65	NS	NS	NS	131	161
Weed management							
Weedy check	101.50	68.50	5.90	27.16	40.84	1678	2136
Weed-free	161.75	107.41	6.29	39.81	41.78	3486	4596
1 hand-hoeing at 30 DAS	151.81	98.19	6.05	32.28	40.91	2971	3949
2, 4-D at 0.5 kg/ha 30 DAS	145.53	89.00	6.12	31.91	40.53	2641	3387
Metsulfuron at 4.0 g/ha 30 DAS	152.63	100.75	6.20	35.00	41.16	3187	4021
2, 4-D at 0.5 kg/ha 30 DAS + 1 hand-hoeing at 45 DAS	156.75	104.16	6.23	36.94	41.38	3300	4323
Metsulfuron at 4.0 g/ha 30 DAS+ 1 hand-hoeing at 45 DAS	158.03	105.75	6.26	38.53	40.84	3354	4403
SEm±	1.78	2.26	0.03	1.06	0.50	41	91
CD (P=0.05)	5.10	6.48	0.10	3.04	NS	117	261

SSB, Stale seed-bed technique; DAS, days after sowing; mrl, meter row length

SSB using shallow tillage. The increased grain yield owing to application of SSB using glyphosate at 2.0 kg/ha was 9.98, and 7.74% than deep and conventional tillage respectively. This was might be owing to significantly more dry-matter accumulation, higher number of effective tiller/m row length and seeds/spike (Table 3) and was also owing to less competition by weeds to wheat particularly of nutrient uptake by weeds (Table 3). These results are in agreement with the findings of Kumar *et al.* (2015) and Khatun *et al*. (2016).

Weed management

All the weed-control treatments resulted in significantly higher grain, straw and biological yields than the weedy check (Table 4). Application of metsulfuron @ 4.0 g/ha + 1 hand-hoeing significantly increased the grain, straw and biological yields over 1 hand-hoeing at 30 DAS and 2, 4-D @ 0.5 kg/ha but was statistically at par with 2, 4-D @ 0.5 kg/ha + 1 hand-hoeing. The increase grain yield because of applied weed-control measures like metsulfuron @ 4.0 g/ha + 1 hand-hoeing, 2, 4-D @ 0.5 kg/ha + 1 hand-hoeing and metsulfuron @ 4.0 g/ha alone was to the extent of 102.13, 98.87 and 92.04% over the weedy check.

The lowest value of yield attributes and yield may be due to severe competition offered by weeds for resources, which made the crop plant incompetent to take up more moisture and nutrients, which consequently adversely affected growth. Poor growth and less uptake of nutrients in weedy check might have produced less photosynthates and partitioned less assimilates to numerous metabolic sink and ultimately poor development of yield components. The higher seed yield obtained with either of these treatments could be better explained by their effectiveness in weed control in comparison to weedy check. Our results at support the findings of Pisal and Sagorka (2013) and Patil *et al.* (2014).

At 7 and 30 DAA, application of metsulfuron at 4.0 g/ha + 1 hand-hoeing significantly lowered the population of fungi, bacteria and dehydrogenase activity compared with 1 hand-hoeing, 2, 4-D @ 0.5 kg/ha and 2, 4-D @ 0.5 kg/ha + 1 hand–hoeing, but statistically at par with metsulfuron @ 4.0 g/ha. However 2, 4-D @ 0.5 kg/ha + 1 hand-hoeing was statistically at par with 2, 4-D @ 0.5 kg/ha at different interval of growth stages. The fungi, bacteria and dehydrogenases activities were higher under weed-free and weedy check as compared to herbicide-treated plot, whereas at harvesting stage, fungi, bacteria and dehydrogenase activity had no significant effect among weed-control treatment. Zabaloy *et al*. (2008) reported similar results.

Slightly lower nutrient uptake by weeds was observed under metsulfuron @ 4.0 g/ha + 1 hand-hoeing and significantly superior results over all the other treatments. However, it was at par with 2, 4-D @ 0.5 kg/ha + 1 hand-hoeing. Nitrogen, phosphorus and potassium uptake by weeds at harvesting stage in weedy check increased by 99.00, 98.06 and 98.36% over metsulfuron 4.0 g/ha + 1 hand-hoe-

Table 3. Effect of crop-establishment and weed management on fungi, bacteria and dehydrogenise activity on pooled basis

Treatment	Fungi population			Bacteria population			Dehydrogenase activity		
	7 DAA	30 DAA	At harvesting	7 DAA	30 DAA	At harvesting	7 DAA	30 DAA	At harvesting
Crop-establishment method									
SSB using shallow tillage	28.73	37.16	50.57	16.48	22.18	45.77	5.32	6.64	8.46
SSB using glyphosate at 2.0 kg/ha	27.68	36.63	50.63	15.45	22.16	45.29	5.27	6.58	8.45
Deep tillage	29.79	39.52	52.63	15.75	22.13	45.96	5.58	6.89	8.74
Conventional tillage	30.57	40.11	53.09	16.07	23.38	47.84	5.67	7.01	8.96
SEm±	1.04	1.00	0.88	0.40	0.45	0.85	0.14	0.15	0.29
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management									
Weedy check	36.59	44.72	53.63	20.78	25.47	47.78	6.90	7.79	8.90
Weed-free	35.00	43.50	52.56	19.94	24.19	45.75	6.85	7.73	8.85
1 hand-hoeing at 30 DAS	35.97	44.41	51.78	20.31	24.56	46.25	6.72	7.47	8.70
2, 4-D at 0.5 kg/ha 30 DAS	25.97	35.16	51.88	14.22	21.88	46.16	5.04	6.53	8.50
Metsulfuron at 4.0 g/ha 30 DAS	23.03	33.19	51.38	11.97	19.59	46.19	3.90	5.72	8.54
2, 4-D at 0.5 kg/ha 30 DAS+ 1 hand-hoeing at 45 DAS	25.56	34.38	49.91	13.25	21.00	45.63	4.93	6.61	8.52
Metsulfuron at 4.0 g/ha 30 DAS + hand-hoeing at 45 DAS	22.22	33.13	50.97	11.09	20.53	45.75	3.89	5.63	8.54
SEm±	0.69	0.98	1.14	0.35	0.77	1.12	0.23	0.18	0.25
CD (P=0.05)	1.97	2.82	NS	1.01	2.19	NS	0.67	0.51	NS

SSB, Stale seed-bed; DAS, days after sowing; DAA, days after application

Table 4. Effect of crop-establishment and weed management nutrient uptake by weeds and wheat on pooled basis

Treatment	Weeds			Grain			Straw		
	Nitrogen	Phosphorous	Potassium	Nitrogen	Phosphorous	Potassium	Nitrogen	Phosphorous	Potassium
Crop-establishment method									
SSB using shallow tillage	3.68	0.81	3.54	52.89	12.20	15.64	23.08	6.84	50.91
SSB using glyphosate at 2.0 kg/ha	3.07	0.71	2.85	56.22	13.55	16.66	23.96	7.70	53.88
Deep tillage	4.42	0.99	4.35	50.49	11.36	14.86	21.08	6.25	49.37
Conventional tillage	4.94	1.09	5.13	49.06	11.01	14.34	20.66	5.73	45.63
SEm±	0.20	0.05	0.16	1.01	0.33	0.41	0.51	0.32	1.10
CD (P=0.05)	0.60	0.16	0.47	3.01	0.99	1.22	1.53	0.94	3.28
Weed management									
Weedy check	15.50	3.57	15.64	29.89	*6.71*	8.48	12.12	3.45	27.14
Weed-free	0.00	0.00	0.00	61.93	14.42	18.59	27.26	8.42	61.85
1 hand-hoeing at 30 DAS	2.44	0.56	2.47	53.31	12.18	15.72	22.22	6.38	50.96
2, 4-D at 0.5 kg/ha 30 DAS	6.53	1.38	6.22	46.39	10.73	13.53	18.87	5.83	43.42
Metsulfuron at 4.0 g/ha 30 DAS	3.39	0.71	3.11	55.62	13.00	16.20	23.11	6.82	51.56
2, 4-D at 0.5 kg/ha 30 DAS + 1 hand-hoeing at 45 DAS	0.19	0.04	0.18	58.56	13.46	17.20	25.66	7.62	56.61
Metsulfuron at 4.0 g/ha 30 DAS + 1 hand-hoeing at 45 DAS	0.15	0.03	0.15	59.46	13.74	17.91	26.12	7.88	58.09
SEm±	0.23	0.08	0.26	1.10	0.45	0.38	0.75	0.30	1.95
CD (P=0.05)	0.67	0.23	0.73	3.15	1.29	1.09	2.15	0.85	5.59

SSB, Stale seed-bed; DAS, days after sowing

ing respectively. These findings are in conformity with those reported Pisal and Sagorka (2013).

Metsulfuron @ 4.0 g/ha + 1 hand-hoeing treatment was found the most superior treatment which controlled the weeds to the extent of 99.11, 98.85, 97.76 and 99.33% of *Chenopodium album*, *Rumex dentatus, Cyperus rotundus* and *Cynodon dactylon* at harvesting, respectively, in comparison to the weedy check. It was closely accompanied by 2, 4-D @ 0.5 kg/ha + 1 hand-hoeing treatment, that registered the pooled herbicides efficiencies of 98.81, 98.64, 98.25, 99.24 and 98.80% in case of *C. album*, *R. dentatus, C. rotundus*, *C. dactylon* and total weeds at harvesting, respectively, in comparison to weedy check.

This may because of the fact that metsulfuron at 4.0 g/ha controlled the *Rumex dentatus* more effectively and reduced the dry matter of this weed compared to 2, 4-D @ 0.5 kg/ha. Regeneration of *R. dentatus* was in noticed in 2, 4-D @ 0.5 kg/ha applied plot and thus increased the dry matter of the weed as compared to metsulfuron-treated plots. Both the herbicides failed to control perennial weeds; however, Malik *et al.* (2000) reported results with integration of 1 hand-hoeing with either of metsulfuron or 2, 4-D which exhibited significant reduction the dry-matter of total weeds. The lowest dry weight of most of the broad-leaf weeds, viz. *Chenopodium album* and *Rumex dentatus* and total weeds at 30, 60 DAS and harvesting were observed under metsulfuron at 4 g/ha + 1 hand-hoeing (Table 1). Similar results were also reported by Singh *et al.* (2017).

CONCLUSION

Based on two year study, it can be concluded that SSB (stale seed bed) using glyphosate method of crop establishment with metsulfuron at 4.0 g/ha at 30 DAS followed by hand hoeing at 45 DAS method of weed management gave better results in almost all parameters.

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