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Herbicide combinations for control of complex weed flora in wheat

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ABSTRACT

A field experiment was conducted in 2014 and 2015 to find out the effect of herbicides on weed dynamics and productivity of wheat under Jharkhand situation. Two hand weeding performed in wheat crop at 30 and 60 DAS recorded significantly reduced weed density and weed dry matter of broad-leaf, grassy, sedges and total weeds at 30 and 60 DAS with WCE of 94.3 and 94.2%, respectively and was similar to post-emergence application of clodinafop 0.06 kg/ha and pre-emergence application of pendimethalin + metribuzin 1.0 kg/ha + 0.175 kg/ha. This resulted in maximum total and effective tillers, grain (3.08 t/ha) and straw (5.37 t/ha) yield and net return (` 32,019.00 and B:C ratio (1.33) compared to other herbicides application.

Key words: Chemical control, Herbicide combination. Relative yield loss, Weed control efficiency, Wheat

Weeds compete with crop species for water, nutrients and light and ultimately reduce crop yield (Cudney *et al.* 2001). The competition of weeds for nutrients may results in such obvious responses as dwarfing in plant size, nutrient starved conditions, wilting and actual dying out of plants (Andreasen *et al.* 1996). Therefore, effective weed management is imperative to produce optimum yields. Among different weed management practices, chemical weed control is preferred (Marwat *et al*. 2008) because of less labor involvement and no mechanical damage to the crop that happens during manual weeding. Moreover, the control is more effective as the weeds even within the rows are killed which invariably escape, because of morphological similarity to wheat. Combination of isoproturon and 2,4-D as tank mixture have been recommended against complex weed flora. This combination has been found promising in the situation where isoproturon was effective against *Phalaris minor*. But against complex weed flora dominated by other weeds, this combination was not so effective. Under such situations, a suitable combination of clodinafop with some broad-spectrum herbicides like sulfosulfuron and metribuzin was needed. Hence, the present investigation was carried out to evaluate the efficacy of pre- and post-emergence herbicides and their combination against mixed weed flora and productivity as well as profitability in wheat production.

MATERIALS AND METHODS

A field experiment was conducted in research farm of Birsa Agricultural University, Ranchi, during winter season of 2014 and 2015 to find out the effect of herbicides on weed dynamics and productivity of wheat under Jharkhand situation. The treatments comprised of pre-emergence application of pendimethalin 0.75 kg/ha, metribuzin 0.021 kg/ha, pendimethalin + metribuzin (1.0 + 0.175 kg/ha), pendimethalin 1.0 kg/ha *fb* sulfosulfuron 0.018 kg/ha, post- emergence application of sulfosulfuron 0.025 kg/ha, clodinafop 0.06 kg/ha, sulfosulfuron 75% + metsulfuron-methyl 20% (0.03 + 0.002 kg/ha), metsulfuron 0.004 kg/ha, mesosulfuron 3% + iodosulfuron0.6% (0.012 + 0.0024 kg/ha), clodinafop 15% + metsulfuron1% (0.06 + 0.004 kg/ ha), along with 2 hand weeding at 30 and 60 DAS and weedy check. The experiment was laid out in a randomized block design with three replications. The experimental soil was low in nitrogen (130 kg/ha) and medium in phosphorus (18 kg/ha) and potash (230 kg/ha). Recommended dose of fertilizer 120:60:40 kg N, P_2O_5 and K_2O/ha, respectively, was applied through urea, di-ammonium phosphate and muriate of potash. Half of the nitrogen, full dose of phosphorus and potassium were applied before sowing. Remaining half of nitrogen was applied in two equal splits at crown root initiation and maximum tillering stages of crop. Crop was sown at spacing of 20 cm on 05th and 19th December, 2014-15 and 2015-16 and harvested on 12th and 24th April, 2015 and 2016, respectively. The yield attributing parameters and yield of the crop were recorded after physiological maturity. Weeds were counted species-wise and differentiated into categories of grass, and broad-leaf and sedges weed. Weed count was expressed as no./m^2. The mean data were subjected

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to square root transformation ($\sqrt{x+0.5}$) to normalize their distribution. Relative percentage composition of weeds of individual weed species was calculated by the formula as suggested by Shetty and Rao (1979).

Relative composition of a species (%) =No. of individual species/ Total no. all weeds X 100.

The relative yield loss (YL) of the crop challenged by weed competition under field conditions was estimated using equation, YL (%) = 1-(YCW/YCM) X 100, where YCW and YCM are crop yields in competition with weeds and in weed-free conditions, respectively.

RESULTS AND DISCUSSION

Major weed flora in wheat crop were broad-leaved weeds like *Coronopus dydimus, Mililotus alba, Vicia sativa, Spergula arvensis, Alternanthera sessilis, Anagalis arvensis* with average relative composition 47.02, 27.63, 3.59, 2.69, 1.51 and 1.50%, respectively, while average relative composition of narrow-leaved weeds like *Sorghum halepense* and *Cynodon dactylon* were 8.21 and 4.90 percent, respectively and sedge *Cyperus rotundus* was 2.95%.

Weed density, dry matter and weed control efficiency

Two hand weeding performed in wheat crop at 30 and 60 DAS recorded significantly reduced weed density as well as weed dry matter of grassy, broad-leaf, sedges and total weeds (**Table 1)** and was similar to post-emergence application of clodinafop 0.06 kg/ ha and pre-emergence application of pendimethalin + metribuzin (1.0 + 0.175 kg/ha) during 2014 and 2015 and also when data were pooled (**Table 2**). Kumar *et al.* (2013) also recorded reduced weed dry matter with clodinafop. In case of dry matter, mesosulfuron 3% + iodosulfuron 0.6% (0.012 + 0.0024 kg/ha) applied as post-emergence was also similar except at 60 DAS during 2015-16 (**Table 3**). Consequently two hand weeding recorded maximum weed control efficiency and was similar to post-emergence

Table 1. Effect of weed control methods on weed density (no./m^2) in wheat

Treatment	Grassy						Broad-leaf weed						Sedges					
	30 DAS			60 DAS			30 DAS			60 DAS			30 DAS			60 DAS		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
Pendimethalin 0.75kg/ha	3.39 (12.0)	2.60 (7.15)	3.03 (9.57)	4.31 (20.1)	7.86 (64.9)	6.36 (42.5)	17.36 (325)	24.93 (641)	21.95 (483)	21.91 (525)	20.85 (469)	21.39 (497)	1.60 (3.67)	3.34 (10.7)	2.74 (7.17)	1.73 (4.58)	4.08 (16.8)	3.31 (10.7)
Sulfosulfuron 0.025kg/ha	5.47 (30.0)	1.56 (3.36)	4.14 (16.7)	6.93 (49.8)	7.98 (65.2)	7.53 (57.5)	22.14 (491)	24.41 (595)	23.30 (543)	27.72 (770)	24.15 (584)	26.01 (677)	3.07 (11)	5.25 (27.3)	4.40 (19.2)	3.97 (19.6)	6.37 (40.2)	5.47 (29.9)
Metribuzin 0.21kg/ha	4.33 (18.3)	2.79 (7.81)	3.67 (13.1)	5.43 (29.6)	7.05 (49.2)	6.30 (39.4)	20.12 (405)	22.18 (492)	21.18 (449)	25.18 (635)	15.07 (297)	21.43 (466)	2.50 (7.67)	1.10 (1.0)	1.99 (4.33)	2.98 (11.7)	4.08 (16.8)	3.81 (14.3)
Clodinafop 0.06kg/ha	2.54 (6.3)	3.7 (14.9)	3.21 (10.6)	3.17 (10.4)	3.91 (15.1)	3.57 (12.7)	10.24 (112)	11.24 (134)	10.75 (123)	12.66 (167)	7.97 (94)	10.90 (131)	1.18 (1.33)	1.18 (1.33)	1.18 (1.33)	1.25 (1.67)	0.71 (0)	1.05 (0.83)
Pendimethalin + metribuzin 1+ 0.175 kg/ha	2.35 (5.7)	3.00 (8.64)	2.71 (7.15)	2.99 (9.8)	4.84 (24.2)	4.10 (17.0)	13.07 (179)	15.00 (251)	14.28 (215)	16.11 (264)	9.37 (144)	13.75 (204)	1.25 (1.67)	1.25 (1.67)	1.25 (1.67)	1.34 (2.08)	0.71 (0)	1.11 (1.04)
Pendimethalin *fb* sulfosulfuron1+ 0.018 kg/ha	2.73 (7.0)	13.71 (190)	9.89 (98.8)	3.41 (11.5)	15.81 (256)	11.44 (133.6)	13.64 (208)	14.32 (212)	14.18 (210)	17.00 (324)	31.84 (1098)	26.03 (711)	1.90 (3.33)	4.88 (23.3)	3.71 (13.3)	2.28 (4.85)	6.79 (45.8)	5.07 (25.3)
Sulfosulfuron + metsulfuron 0.03 + 0.002 kg/ha	5.98 (40.0)	4.78 (22.5)	5.49 (31.3)	7.71 (69.5)	8.20 (76.4)	7.99 (72.9)	22.56 (523)	27.68 (793)	25.35 (658)	28.39 (839)	27.23 (771)	27.82 (805)	4.88 (23.3)	2.82 (7.67)	3.99 (15.5)	6.08 (36.5)	6.44 (40.9)	6.26 (38.7)
Metsulfuron 0.004 kg/ha	6.94 (48.0)	6.66 (50.6)	7.01 (49.3)	8.64 (74.1)	15.40 (241)	12.51 (157)	25.23 (667)	28.93 (895)	27.53 (781)	31.19 (991)	28.92 (970)	30.72 (980)	5.21 (27.3)	5.92 (34.7)	5.59 (31)	6.59 (45.1)	6.93 (48.0)	6.84 (46.5)
Mesosulfuron + iodosulfuron 0.012 +0.0024 kg/ha	3.04 (9.0)	7.63 (57.9)	5.82 (33.4)	3.74 (13.7)	6.10 (37.5)	5.06 (25.6)	12.76 (213)	19.18 (398)	16.57 (306)	15.78 (332)	16.23 (292)	16.16 (312)	1.73 (3)	1.73 (3)	1.73 (3)	2.02 (4.09)	3.92 (15.1)	3.17 (9.6)
Clodinafop + metsulfuron 0.06 + 0.004 kg/ha	12.32 (151)	6.06 (37.2)	9.73 (94.3)	15.47 (240)	6.11 (36.9)	11.76 (138)	26.09 (720)	13.98 (257)	22.03 (488)	33.10 (1194)	9.37 (144)	25.13 (669)	4.40 (30.7)	1.90 (3.33)	3.58 (17)	5.63 (54.9)	0.71 (0)	4.07 (27.4)
2 Hand weeding	1.50 (3.0)	3.33 (10.8)	2.66 (6.90)	1.61 (3.75)	2.39 (6.93)	2.09 (5.34)	8.26 (69)	9.06 (83)	8.67 (76)	10.23 (105)	7.97 (94)	9.71 (99)	1.10 (1)	1.87 (3.67)	1.56 (2.33)	1.16 (1.25)	0.71 (0)	0.99 (0.63)
Unweeded control	12.39 (15)	13.60 (184)	1302 (170)	15.65 (252)	16.38 (272)	16.19 (262)	29.10 (849)	32.18 (1044)	30.68 (946)	36.72 (1374)	34.97 (1295)	35.93 (1334)	5.92 (34.7)	5.55 (30.7)	5.74 (32.7)	7.41 (54.9)	7.36 (54)	7.40 (54.5)
LSD (p=0.05)	1.93	2.19	1.33	2.65	3.53	2.63	8.67	9.79	6.51	11.58	15.44	10.64	2.67	0.97	1.69	3.72	0.97	2.14

Figures in parentheses indicate original values subjected to square root transformation

Table 2. Effect of weed control methods on total weed density (no./m^2) in wheat

Treatment	30 DAS			60 DAS		
	2014	2015	Pool	2014	2015	Pool
Pendimethalin 0.75 kg/ha	17.82(341)	25.29(659)	22.33(500)	22.48(550)	22.78(551)	22.64(550)
Sulfosulfuron 0.025 kg/ha	23.06(532)	25.03(626)	24.06(579)	28.92(839)	26.25(689)	27.63(764)
Metribuzin 0.21 kg/ha	20.76(431)	22.38(501)	21.59(466)	25.99(676)	17.80(363)	22.66(520)
Clodinafop 0.06 kg/ha	10.66(120)	12.04(150)	11.37(135)	13.18(179)	9.64(109)	11.64(144)
Pendimethalin + metribuzin 1 + 0.175 kg/ha	13.36(186)	15.38(261)	14.60(224)	16.49(276)	11.67(169)	14.48(222)
Pendimethalin *fb* sulfosulfuron 1 + 0.018 kg/ha	14.06(218)	20.60(426)	17.88(322)	17.53(341)	36.38(1399)	28.93(870)
Sulfosulfuron + metsulfuron 0.03 + 0.002 kg/ha	23.96(586)	28.25(824)	26.30(705)	30.20(945)	29.27(889)	29.74(917)
Metsulfuron 0.004 kg/ha	26.71(742)	30.39(980)	28.98(861)	33.08(1111)	33.99(1259)	33.91(1185)
Mesosulfuron + iodosulfuron 0.012 + 0.0024 kg/ha	13.31(225)	20.83(459)	17.74(342)	16.47(350)	17.80(345)	17.30(347)
Clodinafop + metsulfuron 0.06 + 0.004 kg/ha	29.40(902)	15.95(298)	24.41(600)	37.26(1489)	12.20(181)	28.24(835)
2 Hand weeding	8.45(73)	9.81(97)	9.16(85)	10.44(110)	8.77(101)	9.97(105)
Unweeded control	32.16(1039)	35.37(1259)	33.81(1149)	40.59(1681)	39.66(1620)	40.15(1651)
LSD (p=0.05)	8.49	9.09	6.09	11.50	13.32	10.31

Figures in parentheses indicate original values subjected to square root transformation

Table 3. Effect of weed control methods on weed dry matter (g/m^2)

Treatment	Grassy						Broad-leaf weed						Sedges					
	30 DAS			60 DAS			30 DAS			60 DAS			30 DAS			60 DAS		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
Pendimethalin 0.75 kg/ha	2.40 (5.65)	4.24 (17.6)	3.46 (11.6)	2.79 (7.88)	8.17 (67.8)	6.13 (37.8)	11.79 (144)	18.89 (358)	15.78 (251)	13.85 (201)	23.16 (559)	19.30 (380)	1.25 (1.65)	2.37 (7.13)	1.99 (4.39)	1.35 (2.15)	6.10 (37.7)	4.47 (19.9)
Sulfosulfuron 0.025 kg/ha	3.87 (15.2)	6.23 (42.2)	5.19 (28.7)	4.51 (20.8)	7.54 (57.0)	6.25 (38.9)	15.31 (235)	19.82 (396)	17.71 (316)	17.88 (320)	9.37 (88.6)	14.29 (204)	2.28 (6.04)	4.62 (24.4)	3.68 (15.2)	2.63 (8.31)	5.42 (29.8)	4.30 (19.1)
Metribuzin 0.21 kg/ha	3.07 (9.2)	2.73 (11.6)	3.03 (10.4)	3.56 (12.5)	7.18 (51.3)	5.68 (31.9)	13.96 (197)	16.69 (314)	15.75 (256)	16.30 (268)	14.03 (226)	15.62 (247)	1.73 (3.08)	1.39 (2.34)	1.65 (2.71)	1.97 (4.3)	3.62 (12.6)	2.98 (8.46)
Clodinafop 0.06 kg/ha	1.81 (2.89)	1.98 (5.85)	2.00 (4.37)	2.08 (4.03)	5.64 (32.2)	4.25 (18.1)	7.17 (55)	8.61 (78)	7.97 (67)	8.33 (74.0)	9.30 (88.3)	8.98 (81.1)	0.98 (0.6)	1.05 (0.85)	1.02 (0.73)	1.03 (0.78)	0.71 (0)	0.90 (0.39)
Pendimethalin + metribuzin 1.0 + 0.175 kg/ha	1.74 (2.84)	2.15 (6.28)	2.09 (4.56)	1.99 (3.95)	4.11 (17.1)	3.25 (10.5)	8.97 (83)	8.62 (78)	8.80 (81)	10.45 (112)	14.03 (227)	12.67 (169)	1.02 (0.75)	1.11 (1.06)	1.07 (0.91)	1.09 (0.98)	0.71 (0)	0.94 (0.49)
Pendimethalin *fb* sulfosulfuron1+0. 018 kg/ha	1.96 (3.44)	11.17 (125)	8.03 (64.2)	2.26 (4.73)	12.97 (170)	9.31 (87.6)	9.14 (88)	24.67 (657)	18.84 (373)	10.72 (123)	20.59 (426)	16.53 (275)	1.41 (1.57)	5.79 (33.7)	4.22 (17.6)	1.59 (2.11)	6.71 (44.6)	4.88 (23.3)
Sulfosulfuron + metsulfuron 0.03 + 0.002 kg/ha	4.24 (20.5)	6.02 (37.7)	5.26 (29.1)	4.96 (28.4)	8.57 (73.0)	7.14 (50.7)	15.91 (270)	23.24 (545)	20.06 (408)	18.55 (366)	23.52 (559)	21.31 (463)	3.40 (11.1)	4.57 (26.5)	4.20 (18.8)	3.96 (15.2)	5.68 (31.8)	4.89 (23.5)
Metsulfuron 0.004kg/ha	4.82 (23.0)	6.08 (38)	5.50 (30.5)	5.61 (31.2)	12.81 (169)	9.91 (100)	17.47 (320)	22.62 (593)	20.72 (456)	20.34 (430)	28.07 (802)	24.67 (616)	3.71 (14.2)	5.13 (28.4)	4.53 (21.3)	4.32 (19.4)	5.63 (31.3)	5.07 (25.4)
Mesosulfuron + iodosulfuron 0.012+0.0024 kg/ha	2.14 (4.09)	2.54 (7.98)	2.44 (6.04)	2.46 (5.59)	6.19 (37.9)	4.71 (21.7)	8.35 (86)	14.10 (203)	11.77 (144)	9.83 (121)	18.15 (370)	14.79 (246)	1.30 (1.39)	1.35 (2.13)	1.34 (1.76)	1.44 (1.83)	3.62 (12.6)	2.78 (7.24)
Clodinafop + metsulfuron 0.06 + 0.004 kg/ha	8.56 (73.6)	5.35 (28.7)	7.14 (51.1)	10.00 (100)	5.64 (32.2)	8.16 (66.3)	17.84 (348)	13.92 (194)	16.23 (271)	20.80 (472)	14.95 (234)	18.50 (353)	2.69 (9.78)	1.30 (1.92)	2.23 (5.85)	3.07 (13.2)	3.45 (13.0)	3.34 (13.1)
2 Hand weeding	1.18 (1.35)	1.30 (1.92)	1.25 (1.63)	1.27 (1.76)	1.63 (3.85)	1.47 (2.8)	5.71 (33)	7.12 (50)	6.46 (41)	6.64 (44.2)	7.69 (58.8)	7.19 (51.5)	0.92 (0.45)	0.99 (0.64)	0.96 (0.54)	0.97 (0.59)	0.71 (0)	0.86 (0.29)
Unweeded control	8.70 (78.6)	12.59 (158)	10.85 (118)	10.16 (107)	13.73 (190)	12.12 (149)	21.05 (462)	28.14 (794)	24.91 (628)	24.60 (631)	30.55 (966)	27.74 (799)	4.89 (26.0)	11.75 (138)	9.04 (82.1)	5.69 (35.4)	14.35 (205)	10.97 (120)
LSD (p=0.05)	1.59	2.73	1.92	1.84	2.42	1.65	6.57	8.23	5.48	7.68	7.87	6.05	1.99	2.64	2.03	2.37	1.09	1.51

Figures in parentheses indicate original values subjected to square root transformation

application of clodinafop 0.06 kg/ha (**Table 4**). In general significant reduction in weed dry weight with application of clodinafop might be due to more effectiveness in controlling broad spectrum weeds than others.

Yield attributing parameters of wheat

Two hand weeding performed in wheat being similar to post-emergence application of clodinafop 0.06 kg/ha, pendimethalin + metribuzin (1.0 + 0.175 kg/ha), pre-emergence application of pendimethalin 1.0 kg/ha *fb* post-emergence application of sulfosulfuron 0.018 kg/ha and mesosulfuron 3% + iodosulfuron 0.6% (0.012 + 0.0024 kg/ha) recorded significantly higher total and effective tillers during 2014, 2015 and under pooled data. Maximum grains/ spike was recorded by pre-emergence application of pendimethalin 1.0 kg/ha *fb* post-emergence application of sulfosulfuron 0.018 kg/ha, similar to pre-emergence application of pendimethalin 0.75 kg/ ha, pendimethalin + metribuzin (1.0 + 0.175 kg/ha) and two hand weeding at 30 and 60 DAS. Maximum

Table 4. Effect of weed control methods on total weed dry matter (g/m²) in wheat

Treatment	30 DAS		60 DAS		Pool		WCE (%)	
	2014	2015	2014	2015	30 DAS	60 DAS	30 DAS	60 DAS
Pendimethalin 0.75 kg/ha	12.10 (151.4)	19.53 (382.4)	14.21 (211.0)	25.29 (665.1)	16.28 (266.9)	20.72 (438.1)	65.56	57.29
Sulfosulfuron 0.025 kg/ha	15.97 (256.2)	21.38 (462.8)	18.66 (349.6)	13.26 (175.5)	18.88 (359.5)	16.19 (262.5)	55.41	73.33
Metribuzin 0.21 kg/ha	14.40 (209.1)	17.20 (328.1)	16.81 (284.6)	16.32 (290.6)	16.19 (268.6)	16.87 (287.6)	64.79	68.93
Clodinafop 0.06 kg/ha	7.45 (58.8)	9.02 (84.6)	8.65 (78.8)	10.89 (120.5)	8.34 (71.7)	9.98 (99.7)	90.61	89.24
Pendimethalin + metribuzin 1 + 0.175 kg/ha	9.18 (86.5)	9.06 (85.6)	10.69 (116.8)	14.76 (243.8)	9.13 (86.1)	13.15 (180.3)	88.55	79.46
Pendimethalin *fb* sulfosulfuron 1 + 0.018 kg/ha	9.44 (93.5)	27.85 (815.9)	11.08 (130.0)	25.24 (641.1)	20.96 (454.7)	19.58 (385.5)	45.40	59.60
Sulfosulfuron + metsulfuron 0.03 + 0.002 kg/ha	16.88 (302.0)	24.62 (609.2)	19.69 (409.7)	25.67 (664.1)	21.21 (455.6)	22.99 (536.9)	43.10	47.45
Metsulfuron 0.004 kg/ha	18.51 (357.2)	24.04 (659.3)	21.56 (480.8)	31.37 (1002.2)	21.93 (508.3)	27.07 (741.5)	40.18	26.21
Mesosulfuron + iodosulfuron 0.012 + 0.0024 kg/ha	8.74 (91.6)	14.44 (212.8)	10.28 (128.4)	19.62 (420.8)	12.08 (152.2)	15.84 (274.6)	79.30	68.72
Clodinafop + metsulfuron 0.06 + 0.004 kg/ha	20.03 (431.2)	14.99 (224.6)	23.37 (585.4)	16.38 (280.1)	17.87 (327.9)	20.51 (432.7)	57.94	56.41
2 Hand weeding	5.84 (34.5)	7.29 (52.7)	6.79 (46.6)	7.92 (62.7)	6.61 (43.6)	7.38 (54.6)	94.34	94.23
Unweeded control	23.28 (567.0)	32.98 (1091.2)	27.21 (773.6)	36.54 (1361.9)	28.61 (829.1)	32.23 (1067.8)	0.00	0.00
LSD (p=0.05)	6.60	7.94	7.71	7.43	5.48	5.92	20.51	18.15

Figures in parentheses indicate original values subjected to square root transformation

Table 5. Effect of weed control methods on yield attributing parameters of wheat

Treatment	Total tiller (no./m²)			Effective tiller (no./m²)			Grains/spike			Spike length (cm)			1000-seed wt. (g)		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
Pendimethalin 0.75 kg/ha	334	277	306	295	246	271	38	31	35	10.07	8.40	9.23	46.13	38.43	42.28
Sulfosulfuron 0.025 kg/ha	324	272	298	276	231	254	33	28	31	9.60	7.99	8.80	44.53	37.11	40.82
Metribuzin 0.21 kg/ha	328	273	300	286	241	264	35	29	32	9.13	7.62	8.38	46.33	38.63	42.48a
Clodinafop 0.06 kg/ha	393	329	361	345	289	317	28	23	26	8.67	7.22	7.94	45.73	38.09	41.91
Pendimethalin + metribuzin 1 + 0.175 kg/ha	383	320	352	340	286	313	38	32	35	7.27	6.22	6.74	46.40	38.69	42.54
Pendimethalin *fb* sulfosulfuron 1 + 0.018 kg/ha	379	319	349	333	279	306	42	35	39	11.17	9.29	10.23	47.67	39.70	43.68
Sulfosulfuron + metsulfuron 0.03 + 0.002 kg/ha	320	268	294	274	228	251	33	28	30	9.13	7.62	8.38	44.87	37.40	41.13
Metsulfuron 0.004 kg/ha	308	258	283	260	217	238	32	27	29	9.33	7.77	8.55	46.87	39.01	42.94
Mesosulfuron + iodosulfuron 0.012 + 0.0024 kg/ha	375	313	344	321	268	294	35	29	32	9.93	8.28	9.10	47.60	39.66	43.63
Clodinafop + metsulfuron 0.06 + 0.004 kg/ha	299	249	274	255	213	234	35	29	32	9.07	7.55	8.31	43.47	36.25	39.86
2 Hand weeding	402	337	370	350	293	321	40	33	36	10.07	8.40	9.23	48.80	40.65	44.73
Unweeded control	289	241	265	246	205	225	24	20	22	8.07	6.73	7.40	41.60	34.68	38.14
LSD (p=0.05)	66.59	90.10	54.01	66.98	87.08	59.28	4.31	6.09	4.30	NS	2.03	NS	1.32	NS	2.41

1000-grain weight was recorded by two hand weeding at 30 and 60 DAS similar to pre-emergence application of pendimethalin 1.0 kg/ha *fb* post-emergence application of sulfosulfuron 0.018 kg/ha, pre-emergence application of pendimethalin + metribuzin (1.0 + 0.175 kg/ha) and post-emergence application of mesosulfuron 3% + iodosulfuron 0.6% (0.012 + 0.0024 kg/ha) during 2014 and under pooled data (**Table 5**). Prolonged weed competition resulted in less number of grains/spike due to shortened ear head consequently less number of grains and less grain weight.

Yield and economics

Two hand weeding performed in wheat at 30 and 60 DAS recorded maximum grain and straw yield, higher net returns and B:C. While among herbicides, post-emergence application of clodinafop 0.06 kg/ha, similar to pre-emergence application of pendimethalin 0.75 kg/ha, pendimethalin + metribuzin (1.0 + 0.175 kg/ha), pendimethalin 1.0 kg/ha as pre-emergence *fb* post-emergence application of sulfosulfuron 0.018 kg/ha, and mesosulfuron 3% + iodosulfuron 0.6% (0.012 +0.0024 kg/ha) recorded 34.26% higher grain yield compared to weedy check, which was due to minimum yield loss percentage (**Table 6).** However, 51.31 and 48.12% higher net returns and B:C ratio was recorded with post-emergence application of clodinafop 0.06 kg/ha as compared to weedy check and was similar to pre-emergence application of pendimethalin + metribuzin

Table 6. Effect of weed control methods on yield of wheat

Treatment	Grain (t/ha)			Straw (t/ha)			Yield loss (%)		
	2014	2015	pooled	2014	2015	pooled	2014	2015	pooled
Pendimethalin 0.75 kg/ha	2.84	2.29	2.57	5.40	4.33	4.86	34.99	35.34	35.16
Sulfosulfuron 0.025 kg/ha	2.57	2.06	2.32	5.31	4.30	4.81	41.26	41.73	41.46
Metribuzin 0.21 kg/ha	2.79	2.26	2.52	5.33	4.30	4.81	36.25	36.25	36.25
Clodinafop 0.06 kg/ha	3.42	2.74	3.08	5.94	4.80	5.37	21.76	22.50	22.09
Pendimethalin + metribuzin 1 + 0.175 kg/ha	3.28	2.66	2.97	5.56	4.46	5.01	25.01	24.85	24.92
Pendimethalin *fb* sulfosulfuron 1 + 0.018 kg/ha	2.95	2.38	2.67	5.52	4.43	4.97	32.50	32.68	32.58
Sulfosulfuron + metsulfuron 0.03 + 0.002 kg/ha	2.52	2.01	2.26	5.07	4.10	4.59	42.51	43.14	42.77
Metsulfuron 0.004 kg/ha	2.41	1.95	2.18	4.95	4.00	4.47	45.01	44.95	44.97
Mesosulfuron + iodosulfuron 0.012 + 0.0024 kg/ha	2.84	2.31	2.58	5.42	4.38	4.90	35.02	34.72	34.88
Clodinafop + metsulfuron 0.06 + 0.004 kg/ha	2.35	1.90	2.12	4.74	3.81	4.28	46.24	46.40	46.31
2 Hand weeding	4.38	3.54	3.96	6.25	5.04	5.65	0.00	0.00	0.00
Unweeded control	2.24	1.81	2.03	4.42	3.57	4.00	48.75	48.83	48.79
LSD (p=0.05)	0.72	0.59	0.65	0.91	0.83	0.76			

Table 7. Effect of weed control methods on economics of wheat production

Treatment	Cost of cultivation ($x10^3$ `/ha)	Gross return ($x10^3$ `/ha)			Net return ($x10^3$ `/ha)			B:C		
		2014	2015	pooled	2014	2015	pooled	2014	2015	pooled
Pendimethalin 0.75 kg/ha	24.08	53.15	42.72	47.94	29.08	18.64	23.86	1.21	0.77	0.99
Sulfosulfuron 0.025 kg/ha	23.11	49.35	39.69	44.52	26.24	16.57	21.40	1.14	0.72	0.93
Metribuzin 0.21 kg/ha	23.64	52.25	42.21	47.23	28.60	18.56	23.58	1.21	0.79	1.00
Clodinafop 0.06 kg/ha	24.16	62.32	50.04	56.18	38.16	25.88	32.02	1.58	1.07	1.33
Pendimethalin + metribuzin 1+0.175 kg/ha	25.34	59.34	47.93	53.64	34.00	22.59	28.30	1.34	0.89	1.12
Pendimethalin *fb* sulfosulfuron1+0.018 kg/ha	24.89	54.95	44.23	49.59	30.06	19.34	24.70	1.21	0.78	0.99
Sulfosulfuron + metsulfuron 0.03+0.002 kg/ha	23.08	47.91	38.46	43.18	24.82	15.37	20.10	1.08	0.67	0.87
Metsulfuron 0.004 kg/ha	23.33	46.12	37.28	41.70	22.79	13.95	18.37	0.98	0.60	0.79
Mesosulfuron + iodosulfuron 0.012+0.0024 kg/ha	25.88	53.22	43.15	48.18	27.33	17.26	22.30	1.06	0.67	0.86
Clodinafop + metsulfuron 0.06 + 0.004 kg/ha	25.66	44.78	36.09	40.44	19.12	10.43	14.78	0.75	0.41	0.58
2 Hand weeding	28.73	75.62	61.11	68.37	46.89	32.37	39.63	1.63	1.13	1.38
Unweeded control	22.73	42.41	34.24	38.32	19.67	11.50	15.59	0.87	0.51	0.69
LSD (p=0.05)		9.71	8.43	8.98	9.71	8.43	8.98	0.40	0.34	0.37

1.0 + 0.175 kg/ha (**Table 7**). These results were in conformity with Singh *et al.* (2017).

It was concluded that post-emergence application of clodinafop 0.06 kg/ha or pre-emergence application of pendimethalin + metribuzin (1.0 + 0.175 kg/ha) was as good as two hand weeding performed in wheat at 30 and 60 DAS for higher productivity and profitability.

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