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Integrated weed management practices for rice under aerobic culture

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ABSTRACT

A field experiment was conducted to study the effect of irrigation and weed management practices of rice under aerobic culture, laid in split plot design. Among the irrigation schedules, IW/CPE ratio of 1.2 produced significantly higher stature of yield attributes, *viz.*, total number of panicles/m^2, total number of grains/ panicle and number of filled grains/panicle and grain and straw yield were distinctly superior to other two irrigation schedules. At all the stages, with exception at 20 DAS, the lowest of density of weeds and their corresponding dry weight was recorded with hand weeding at 20 and 40 DAS, which were comparable with oxadiargyl 0.07 kg/ha supplemented with HW at 40 DAS for density of grasses, triasulfuron 0.006 kg/ha supplemented with HW at 40 DAS for density of broad leaved weeds and bensulfuron methyl 0.06 kg/ha supplemented with HW at 40 DAS for density of sedges. The highest density of these entire weed categories was recorded with unweeded check. The study revealed that rice can be successfully grown under aerobic culture in north coastal zone of Andhra Pradesh, with pre-emergence application of oxadiargyl 0.07 kg/ha supplemented with HW at 40 DAS for higher productivity.

Key words: Aerobic rice, Bensulfuron-methyl, Chemical control, IW/CPE, Oxadiargyl

To fulfill the increased rice demand with shrinking resources, it will be necessary to increase yield in a unit area with less water. Water is a looming crisis due to competition among agricultural, industrial, environmental and domestic users. The new concept of aerobic rice entails the use of nutrient-responsive cultivars that are adapted to aerobic culture aiming at yields of 70-80% of high input flooded rice. The target environments are irrigated lowlands, where water is insufficient to keep lowland (rainfed or irrigated) paddy fields flooded and favorable uplands with access to supplementary irrigation. The successful transition from traditional lowland cultivation to aerobic rice production should be invariably under conditions of effective water management, to keep the soil ‘‘wet’’ but not flooded or saturated. In practice, irrigation has to be applied to bring the soil water content up to field capacity once a lower threshold has been reached and hence for aerobic rice, the optimum threshold for re-irrigation still needs to be determined.

Weeds are the greatest threat under upland or aerobic rice systems, resulting in yield losses between 30 and 98% (Oerke and Dehne 2004). Successful aerobic rice culture will largely depend on effective weed control. The use of herbicides causes environmental pollution and induces the proliferation of resistant weed biotypes. These risks and the costs of labour for weeding prompt research on environment friendly, low volume and labour efficient methods of weed control for aerobic rice. North Coastal region of Andhra Pradesh is having substantial area under rainfed/semi-dry rice and has a vast scope of growing rice under aerobic conditions. In this backdrop, the present study was undertaken with the objectives to determine the best irrigation water management practice and to find out the effective weed management practice for aerobic rice for maximum performance of aerobic rice.

MATERIALS AND METHODS

An experiment for water and weed management practices in aerobic rice was carried out during *Kharif* 2007 and 2008 at upland block of college farm, Agricultural College, Naira campus of Acharya N.G. Ranga Agricultural University, Andhra Pradesh, situated at 18.24^0 N latitude, 83.84^o E longitude and at an altitude of 27 m above mean sea level in the North coastal zone of Andhra Pradesh. Weather parameters *viz*., temperature, RH, bright sunshine hours and evaporation varied negligibly between *Kharif*, 2007 and 2008. The weather parameters, during both years of study did not deviate much from the normal values of the location and were favorable for the optimal performance of the crop. During the crop period during *Kharif* 2007, a total amount of 488.5 mm rainfall was received in 28 rainy days as against the decennial average of 595 mm received in 32 rainy days for the corresponding period and during *Kharif* 2008, a total amount of 444.5 mm rain-

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fall was received in 28 rainy days as against the decennial average of 592 mm received in 32 rainy days for the corresponding period.

The experiment was laid out in split-plot design and replicated thrice. The treatments consisted of three irrigation schedules (M_1- IW/CPE ratio of 0.8, M_2- IW/CPE ratio of 1.0 and M_3- IW/CPE ratio of 1.2) and five weed management practices (S_1- unweeded check, S_2- hand weeding (HW) twice at 20 and 40 DAS, S_3- pre-emergence application of oxadiargyl 0.07 kg/ha + hand weeding at 40 DAS, S_4- pre-emergence application of bensulfuron-methyl 0.06 kg/ha + hand weeding at 40 DAS and S_5- pre-emergence application of triasulfuron 0.006 kg/ha + hand weeding at 40 DAS as sub-plots. A fertilizer dose of 120-60-50 kg N, P_2O_5 and K_2O/ha was applied uniformly to all the experimental plots. Nitrogen was applied in four equal splits, one each at basal, active tillering panicle initiation and heading stages. The variety '*Vasundhara'* was used with nitrogen level of 120 kg/ha during both the years of the experiment. All the other cultural practices were followed as per the recommended package of practices.

The seed of rice was directly sown in lines in the non-puddled and non-flooded soil. The seed was treated with fungicide carbendazim 1 g/kg seed and then dibbled one seed/hill with a spacing of 20 x 10 cm. Thinning and gap filling were done at 10 DAS to maintain the uniform plant stand in all the plots. The data recorded on various growth and yield parameters of rice crop were analysed following standard statistical analysis of variance procedure as suggested by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

The weed flora of experimental field consisted of seven species of grasses, three species of sedges and ten species of broadleaved weeds (BLW). Among the grasses, *Echinochloa crusgalli* was the predominant species followed by *Cynodon dactylon* and *Dactyloctenium aegypticum* (Table 1). Among the sedges, the dominant species was *Cyperus rotundus,* followed by *Cyperus difformis*. Among the BLW, *Celosia argentea* and *Cyanotis cucullata* were predominant during both the years of study. The density of weeds was influenced by irrigation schedules only at harvest during the first year and at 60 DAS and harvest of rice crop during the second year. At these stages, the lowest density of weeds and their dry weight were observed with irrigations scheduled at IW/CPE ratio of 1.2 (M^3), which were significantly lower than that with the other two irrigation schedules tried (Table 2).

Effect on weeds

The lowest density of grasses at 20 DAS was recorded with oxadiargyl 0.07 kg/ha supplemented with hand weeding (HW) at 40 DAS (S_3) during both the years of study. Pre-emergence application of triasulfuron 0.006 kg/ha along with HW at 40 DAS (S_5) was the next best treatment. The highest density of grasses was recorded with unweeded check (S_1), which was however, on par with hand weeding at 20 and 40 DAS (S_2) (hand weeding at 20 DAS was not imposed by that time). At 40, 60 DAS and at harvest, the lowest density of grasses at 40 DAS was recorded with hand weeding at 20 and 40 DAS (S_2) during both the years which was comparable with pre-emergence application of oxadiargyl 0.07 kg/ha supplemented with HW at 40 DAS (S_3) and both of them were significantly effective in suppressing grasses than with the rest of the treatments. Pre-emergence application of triasulfuron 0.006 kg/ha along with HW at 40 DAS (S_5) was in parity with pre-emergence application of bensulfuron-methyl 0.06 kg/ha with hand weeding at 40 DAS (S_4). The highest density of grasses was recorded with unweeded check (S_1).

At 20 DAS, the lowest broad leaved weeds (BLW) density among the weed management practices was recorded with pre-emergence application of triasulfuron 0.006 kg/ha along with HW at 40 DAS (S_5) during both the years. Oxadiargyl 0.07 kg/ha coupled with HW at 40 DAS (S_3) was the next best treatment followed by pre emergence application of bensulfuron-methyl 0.06 kg/ha coupled with hand weeding at 40 DAS (S_4). The highest BLW density was recorded with unweeded check (S_1), which was however on par with hand weeding at 20 and 40 DAS (S_2) (hand weeding at 20 DAS was not imposed by that time).

At 40, 60 DAS and at harvest the lowest BLW density among the weed management practices was recorded with hand weeding at 20 and 40 DAS (S_2) during both the years of study and was at par with the pre-emergence application of triasulfuron 0.006 kg/ha integrated with HW at 40 DAS (S_5). Oxadiargyl 0.07 kg/ha integrated with HW at 40 DAS (S_3) was comparable with the pre-emergence application of bensulfuron-methyl 0.06 kg/ha integrated with hand weeding at 40 DAS (S_4). The highest BLW density was recorded with unweeded check (S_1).

At 20 DAS the lowest sedge density was recorded with pre-emergence application of bensulfuron-methyl 0.06 kg/ha combined with hand weeding at 40 DAS (S_4) during both the years of study (Table 3). Pre-emergence

Table 1. Density of grasses/m² under aerobic culture rice as influenced by irrigation schedules and weed management practices

Treatment	2007				2008			
	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest
Irrigation schedule								
M_1	63.78 (8.02)	65.70 (8.14)	46.87 (6.88)	63.21 (7.98)	80.29 (8.99)	82.10 (9.09)	60.72 (7.82)	73.12 (8.58)
M_2	62.01 (7.91)	62.94 (7.96)	44.23 (6.69)	61.27 (7.86)	78.74 (8.90)	80.06 (8.98)	59.14 (7.72)	71.07 (8.46)
M_3	59.06 (7.72)	63.23 (7.98)	42.37 (6.55)	54.14 (7.39)	77.44 (8.83)	78.03 (8.86)	54.78 (7.44)	64.00 (8.03)
LSD (P=0.05)	NS	NS	NS	0.43	NS	NS	0.25	0.41
Weed management practice								
S_1	106.00 (10.32)	121.29 (11.04)	152.74 (12.38)	141.69 (11.92)	133.93 (11.59)	162.82 (12.78)	175.98 (13.28)	165.43 (12.88)
S_2	95.34 (9.79)	22.64 (4.81)	14.14 (3.83)	19.56 (4.48)	133.56 (11.58)	32.33 (5.73)	23.50 (4.90)	29.68 (5.49)
S_3	11.82 (3.51)	24.50 (5.00)	15.18 (3.96)	23.23 (4.87)	16.47 (4.12)	35.74 (6.02)	26.25 (5.17)	32.82 (5.77)
S_4	66.25 (8.17)	82.07 (9.09)	20.85 (4.62)	64.00 (8.03)	71.22 (8.47)	90.42 (9.54)	33.15 (5.80)	68.00 (8.28)
S_5	28.66 (5.40)	69.25 (8.35)	19.56 (4.48)	49.23 (7.05)	38.94 (6.28)	78.99 (8.92)	32.18 (5.72)	51.11 (7.18)
LSD (P=0.05)	1.25	0.79	0.38	1.28	0.99	0.66	0.46	1.32

Figures in parentheses indicate square root transformed ($\sqrt{x + 0.5}$) values

Table 2. Density of broad leaved weeds/m² under aerobic rice culture as influenced by irrigation schedules and weed management practices

Treatment	2007				2008			
	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At Harvest
Irrigation schedule								
M_1	21.92 (4.73)	30.75 (5.59)	18.91 (4.41)	22.53 (4.80)	27.53 (5.29)	36.22 (6.06)	24.00 (4.95)	26.41 (5.19)
M_2	22.81 (4.83)	30.42 (5.56)	18.14 (4.32)	21.60 (4.70)	26.18 (5.17)	35.50 (6.00)	22.10 (4.75)	23.50 (4.90)
M_3	20.96 (4.63)	29.41 (5.47)	17.41 (4.23)	17.44 (4.24)	25.34 (5.08)	34.43 (5.91)	19.17 (4.44)	15.16 (3.96)
LSD (P=0.05)	NS	NS	NS	0.35	NS	NS	0.24	0.66
Weed management practice								
S_1	43.06 (6.60)	59.39 (7.74)	72.67 (8.55)	60.09 (7.78)	44.66 (6.72)	71.07 (8.46)	78.19 (8.87)	57.89 (7.64)
S_2	35.02 (5.96)	16.23 (4.09)	3.87 (2.09)	8.19 (2.95)	39.70 (6.34)	20.02 (4.53)	6.84 (2.71)	10.00 (3.24)
S_3	9.99 (3.24)	28.01 (5.34)	4.35 (2.20)	11.45 (3.46)	13.56 (3.75)	28.66 (5.40)	7.78 (2.88)	13.72 (3.77)
S_4	18.42 (4.35)	30.19 (5.54)	5.84 (2.52)	13.19 (3.70)	29.93 (5.52)	33.26 (5.81)	8.95 (3.07)	15.67 (4.02)
S_5	3.02 (1.88)	17.14 (4.20)	4.04 (2.13)	9.67 (3.19)	3.91 (2.10)	23.90 (4.94)	7.00 (2.74)	11.22 (3.42)
LSD(P=0.05)	0.74	0.27	0.34	0.25	0.67	0.42	0.31	0.27

Figures in parentheses indicate square root transformed ($\sqrt{x + 0.5}$) values

Table 3. Density of sedges/m^2 under aerobic rice culture as influenced by irrigation schedules and weed management practices

Treatment	2007				2008			
	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At Harvest
Irrigation schedule								
M_1	14.04	23.98	16.94	25.86	17.72	29.43	20.31	35.16
	(3.81)	(4.95)	(4.18)	(5.13)	(4.27)	(5.47)	(4.56)	(5.97)
M_2	14.50	23.35	16.48	24.60	16.86	28.78	19.33	34.10
	(3.87)	(4.88)	(4.12)	(5.01)	(4.17)	(5.41)	(4.45)	(5.88)
M_3	13.71	22.53	14.40	22.99	17.25	27.84	16.50	30.77
	(3.77)	(4.80)	(3.86)	(4.85)	(4.21)	(5.32)	(4.12)	(5.59)
LSD (P=0.05)	NS	NS	NS	0.14	NS	NS	0.23	0.23
Weed management practice								
S_1	32.74	53.82	61.76	70.34	39.95	47.18	57.51	70.89
	(5.77)	(7.37)	(7.89)	(8.42)	(6.36)	(6.91)	(7.62)	(8.45)
S_2	29.91	12.65	4.01	10.12	37.11	18.56	8.81	15.89
	(5.51)	(3.63)	(2.12)	(3.26)	(6.13)	(4.37)	(3.05)	(4.05)
S_3	3.21	22.46	4.60	14.66	4.26	37.11	9.10	29.80
	(1.93)	(4.79)	(2.26)	(3.89)	(2.18)	(6.13)	(3.10)	(5.50)
S_4	1.69	13.36	4.31	11.65	1.98	18.68	8.90	17.76
	(1.48)	(3.72)	(2.19)	(3.49)	(1.57)	(4.38)	(3.07)	(4.27)
S_5	2.87	14.15	5.05	15.65	3.07	21.88	9.25	32.32
	(1.84)	(3.83)	(2.36)	(4.02)	(1.89)	(4.73)	(3.12)	(5.73)
LSD (P=0.05)	0.28	0.37	0.25	0.35	0.30	0.36	0.28	0.54

Figures in parentheses indicate square root transformed ($\sqrt{x + 0.5}$) values

Table 4. Total weed density/m^2 under aerobic rice culture as influenced by irrigation schedules and weed management practices

Treatment	2007				2008			
	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest
Irrigation schedule								
M_1	99.74	120.43	82.72	111.60	125.54	147.75	105.03	134.99
	(10.01)	(11.00)	(9.12)	(10.59)	(11.23)	(12.18)	(10.27)	(11.63)
M_2	99.32	116.71	78.85	107.47	121.78	144.34	100.57	128.67
	(9.99)	(10.83)	(8.91)	(10.39)	(11.06)	(12.03)	(10.05)	(11.37)
M_3	93.73	115.17	74.18	94.57	120.03	140.30	90.45	109.93
	(9.71)	(10.75)	(8.64)	(9.75)	(10.98)	(11.87)	(9.54)	(10.51)
LSD (P=0.05)	NS	NS	NS	0.26	NS	NS	0.24	0.31
Weed management practice								
S_1	181.80	234.50	287.17	272.12	218.54	281.07	311.68	294.21
	(13.50)	(15.33)	(16.96)	(16.51)	(14.80)	(16.78)	(17.67)	(17.17)
S_2	160.27	51.52	22.02	37.87	210.37	70.91	39.15	55.57
	(12.68)	(7.21)	(4.75)	(6.19)	(14.52)	(8.45)	(6.30)	(7.49)
S_3	25.02	74.97	24.13	49.34	34.29	101.51	43.13	76.34
	(5.05)	(8.69)	(4.96)	(7.06)	(5.90)	(10.10)	(6.61)	(8.77)
S_4	86.36	125.62	31.00	88.84	103.13	142.36	51.00	101.43
	(9.32)	(11.23)	(5.61)	(9.45)	(10.18)	(11.99)	(7.17)	(10.10)
S_5	34.55	100.54	28.65	74.55	45.92	124.77	48.43	94.65
	(5.92)	(10.05)	(5.40)	(8.66)	(6.81)	(11.19)	(6.99)	(9.75)
LSD (P=0.05)	1.55	1.38	0.31	1.62	1.53	1.10	0.36	1.30

Figures in parentheses indicate square root transformed ($\sqrt{x + 0.5}$) values application of triasulfuron 0.006 kg/ha along with HW at 40 DAS (S_5) was the next best treatment and was at par with oxadiargyl 0.07 kg/ha supplemented with HW at 40 DAS (S_3). The highest sedge density was recorded with unweeded check (S_1), which was however, on par with hand weeding at 20 and 40 DAS (S_2) (hand weeding at 20 DAS was not imposed by that time).

At 40, 60 DAS and at harvest, the lowest sedge density was recorded with hand weeding at 20 and 40 DAS (S_2) (hand weeding at 40 DAS was not imposed by that time), which was however, comparable with pre-emergence application of bensulfuron-methyl 0.06 Kg/ha integrated with hand weeding at 40 DAS (S_4) and pre-emergence application of triasulfuron 0.006 kg/ha integrated with HW at 40 DAS (S_5). All these treatments were significantly inferior to oxadiargyl 0.07 kg/ha supplemented with HW at 40 DAS (S_3). Unweeded check (S_1) recorded the highest sedge density.

The lowest total weed count at 20 DAS was recorded with oxadiargyl 0.07 kg/ha supplemented with HW at 40 DAS (S_3), which was comparable with pre-emergence application of triasulfuron 0.006 kg/ha integrated with HW at 40 DAS (S_5) and both of them were significantly lower than the rest of weed management practices studied (Table 4). Pre emergence application of bensulfuron methyl 0.06 kg/ha with hand weeding at 40 DAS (S_4) was the next best treatment. The highest total weed density was recorded with unweeded check (S_1), which was however, on par with hand weeding at 20 and 40 DAS (S_2) during both the years of study (hand weeding at 20 DAS was not imposed by that time).

The lowest total weed count at 40, 60 DAS and at harvest was recorded with hand weeding at 20 and 40 DAS (S_2) during both the years of study. Oxadiargyl 0.07 kg/ha supplemented with HW at 40 DAS (S_3), the next best treatment. Pre-emergence application of triasulfuron 0.006 kg/ha along with HW at 40 DAS (S_5) was at par with pre-emergence application of bensulfuron-methyl 0.06 kg/ha along with HW at 40 DAS (S_4). The highest total weed density was recorded with unweeded check (S_1).

WCE was not significantly influenced by irrigation schedules at any stage of growth during both the years of study (Table 5). The highest WCE at 20 DAS of crop was noticed with oxadiargyl 0.07 kg/ha supplemented with HW at 40 DAS (S_3) and at all the other stages it was recorded with hand weeding at 20 and 40 DAS (S_2) , which was comparable with oxadiargyl 0.07 kg/ha supplemented with HW at 40 DAS (S_3). The lowest WCE was recorded with unweeded check (S_1).

Effect on crop

Yield attributes *viz*., number of panicles/m^2 and number of filled grains/panicle were the highest with irrigation scheduled at IW/CPE ratio of 1.2 (M_3), which were significantly higher than with other two irrigation schedules tried. These parameters with irrigation scheduled at IW/CPE of 1.0 (M_2) were comparable with irrigation scheduled at IW/CPE ratio of 0.8 (M_1) which produced the lowest number of panicles/m^2 and number of filled grains/panicle. Within different weed management practices tried, hand weeding at 20 and 40 DAS (S_2) produced the highest number of panicles/m^2 and number of filled grains/panicle, which were, at par with pre-emergence application of oxadiargyl 0.07 kg/ha supplemented with HW at 40 DAS (S_3). Pre-emergence application of triasulfuron 0.006 kg/ha along with HW at 40 DAS (S_5) was comparable with pre-emergence application of bensulfuron-methyl 0.06 kg/ha with hand weeding at 40 DAS (S_4). The lowest values of these parameters were recorded with unweeded check (S_1) during both the years of study (Table 6).

The highest grain yield was recorded with the irrigations scheduled at IW/CPE ratio of 1.2 (M_3), which were significantly higher than with rest of the irrigation schedules tried. Irrigation scheduled at IW/CPE ratio of 1.0 (M_2) and 0.8 (M_1) were comparable with each other. Among the weed management practices, hand weeding at 20 and 40 DAS (S_2) recorded the highest grain yield and were comparable with pre-emergence application of oxadiargyl 0.07 kg/ha supplemented with HW at 40 DAS (S_3), which in turn were comparable with pre-emergence application of triasulfuron 0.006 kg/ha along with HW at 40 DAS (S_5). The next best treatment was pre-emergence application of bensulfuron-methyl 0.06 kg/ha with hand weeding at 40 DAS (S_4), which was comparable with pre-emergence application of triasulfuron 0.006 kg/ha along with HW at 40 DAS (S_5). The lowest grain yield was recorded with unweeded check (S_1) during both the years of study (Table 6).

The elevated stature of these parameters might be presumably due to the increased moisture content and thereby the effective translocation of photosynthates efficiently to sink, contributing to the better development of yield contributing characters These results are in conformity with those of Maheswari *et al.* (2007), Lin Xian Qing *et al.* (2005). The lowest stature of yield attributes of rice under aerobic culture was noticed with irrigation schedule at IW/CPE ratio of 0.8. Similar findings were reported by Belder *et al.* (2005). Grain yield of rice increased significantly with increase in irrigation schedule from 0.8 to

Table 5. WCE (%) at different stages of rice under aerobic culture as influenced by irrigation schedules and weed management practices

Treatment	2007				2008			
	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest
Irrigation schedule								
M_1	50.35	66.94	75.01	63.06	49.87	64.86	69.94	59.67
M_2	50.50	67.79	75.21	63.14	50.22	65.06	72.05	59.57
M_3	50.70	67.89	76.01	65.02	50.55	65.44	75.81	62.92
Weed management practice								
S_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S_2	3.35	93.43	95.39	86.94	3.48	91.30	92.27	84.83
S_3	91.31	86.80	94.84	81.76	89.14	82.15	91.36	79.28
S_4	70.07	75.78	92.70	73.39	72.96	72.89	89.21	69.15
S_5	87.85	81.69	93.56	76.59	85.46	79.23	90.15	70.34

Table 6. Yield attributes and yield of rice under aerobic culture as influenced by irrigation schedules and weed management practices

Treatment	Panicles/m^2		Filled grains/ panicle		1000 - grain weight (g)		Grain yield (kg/ha)	
	2007	2008	2007	2008	2007	2008	2007	2008
Irrigation schedule								
M_1	147	145	117	112	23.42	23.13	4095	3957
M_2	149	146	121	118	23.82	23.41	4230	4073
M_3	161	158	133	132	23.91	23.79	4702	4547
LSD (P=0.05)	9	8	11	7	NS	NS	432	399
Weed management practice								
S_1	81	79	51	41	23.25	22.96	803	691
S_2	183	180	156	152	24.11	23.84	5761	5595
S_3	179	176	150	146	23.93	23.67	5561	5392
S_4	155	152	126	127	23.49	23.25	4530	4367
S_5	164	161	137	137	23.80	23.50	5055	4915
LSD (P=0.05)	16	15	13	10	NS	NS	674	648

1.2. The improvement in yield was due to better availability of moisture, which in turn lead to efficient physiological activity. High level of dry matter production and efficient translocation of photosynthates from source to sink might be responsible for the production of increased level of yield structure. Rice plants when grown under saturated condition, develop more plant stature, leaf area, root volume, productive tillers, resulting in higher yields. These results are in accordance with those of Jadhav *et al.* (2003), Singh *et al.* (2003) Ambrocio Castaneda *et al.* (2004) and Maheswari *et al.* (2007). The highest straw yield was observed with I_3, which was significantly superior to other levels and the lowest straw yields were associated with I_1.

Density of total weeds, grasses and BLWs increased up to 40 DAS and then decreased towards 60 DAS and again increased towards harvest of the crop. However, the rate of decrease was marginal. This might be due to the alternate wetting and drying conditions due to scheduling of irrigations based on IW/CPE ratio. However, the rate of increase of the density of sedges was more than grasses or BLWs towards the harvest of crop, indicating the ability of sedges to proliferate under wide varying conditions of soil moisture.

In general, the density of grasses was higher followed by BLWs and sedges. However, towards the later stages of crop growth, irrigations scheduled at IW/CPE ratio of 1.2, during both the years, resulted in significantly lesser total weed density including grasses, sedges and BLWs and their corresponding dry weights than with other irrigation schedules studied. This might be due to the favourable growing conditions created for crop growth upon the receipt of more irrigations than the other irrigation schedules, during both the years, which might have smothered the growth of weeds, thus depriving them of the basic growth resources and thereby resulting in reduced crop weed competition at later stages of crop growth. However, the WCE of all the irrigation schedules at all stages of crop growth were non significant. These results are in conformity with those of Samar Singh *et al.* (2008) and Subramanyam *et al.* (2007).

Weed management practices exerted significant influence on yield attributes of rice under aerobic rice *viz.*, number of panicles/m^2 and number of filled grains/panicle. The highest stature of the yield attributes was attained with the hand weeding at 20 and 40 DAS and pre-emergence application of oxadiargyl 0.07 kg/ha with hand weeding at 40 DAS. This may be attributed to the fact that effective weed management at critical stages of the crop weed competition, thereby the yield attributes were the highest with S_2. Similar results have been reported by Sharma *et al.* (2007) and Ramana *et al.* (2007).

The highest grain yield was obtained with hand weeding at 20 and 40 DAS and pre-emergence application of oxadiargyl 0.07 kg/ha with hand weeding at 40 DAS during both the years of investigation. This might be due to the fact that hand weeding at 20 and 40 DAS and pre emergence application of oxadiargyl 0.07 kg/ha with hand weeding at 40 DAS in rice under aerobic culture will reduce the weed competition and thereby there is improvement in yield attributes, resulting in higher grain yield. The superior performance of oxadiargyl could be attributed to the fact that it is a potent inhibitor of protox, deregulates the porphyrin pathway. Further to the action of chemical, the superior performance could also be attributed to the manual removal of existing vegetation without sparing any individual group of weeds through hand weeding at 40 DAS. These results are in accordance with those of Arul Chezhian and Kathiresan (2008), Rajkhowa *et al.* (2005) and Samar Singh *et al.* (2005).

In conclusion, the study revealed that rice can be successfully grown under aerobic culture in north coastal zone of Andhra Pradesh, with pre-emergence application of oxadiargyl 0.07 kg/ha supplemented with HW at 40 DAS for higher productivity.

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Effect of density and dose of herbicide on entry, translocation and root exudates in water hyacinth

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ABSTRACT

Spraying of foliar herbicide to control water hyacinth may lead to mortality of the fish by root exudation of herbicide or accidental drift of herbicide. To overcome herbicide-divalent cations complex formation in hard water at improper pH, increasing herbicide dosage per drop, either by increase of dosage or by reduce the spray volume, was one of the techniques. Using radioactive ^{14}C-glyphosate and ^{14}C-2,4-D, effect of dosage on herbicide retained on the cuticle as dried out residue, distribution with in plant system and moved out as root exudates was assessed. Twice the recommended concentration (2x) of herbicide per drop and drop density per fed spot significantly increased the dried residue on the cuticle 67 to 91 and 68 to 79% over total activity recovered compared to x dose for glyphosate and 2,4-D, respectively. 2,4-D (2x) significantly increased the amount of herbicide cuticle loading and mobility within cuticle but differences in translocation to different parts was not significant except in root (2x had lower activity than x). Similarly, significant difference between 2x and x for glyphosate was observed for cuticle loading and root exudates. At 2x dosage, root exudates of both herbicides was more after 8 days. Half-life in pond water was around 5 days for both herbicides compared to normal water 7 and 11days of glyphosate and 2,4-D respectively. The chances of hherbicide toxicity to fishes were unlikely by foliar applied herbicides.

Key words: Aquatic weed, Chemical control, Dosage, *Eichhornia crassipes,* Herbicide

Eichhornia crassipes is a floating weed with rosettes of leathery, waxy, green leaves attached to thick, spongy (inflated for floatation) petiole. Dark feathery roots that typically hang suspended in the water below the plant and have attractive lavender flowers. Water hyacinth was introduced to remove heavy metal toxicity from pond but owing to its high transpiration rate it has become a threat to irrigation water. Mortality of fish was observed when herbicide was used to kill water hyacinth. High density of fine drops of foliage herbicide known to increase dried residue, entry and translocation in various weed species compared to single coarse drop (Anonymous 2005). Reducing volume of spray 194 to 24 l/ha or enhanced dosage eliminated the antagonistic effect of ionized glyphosate chelating with calcium, magnesium present in hard water spray solution (Buhler and Burnside 1983). Thus with this background, experiments were conducted 1) to assess the effect of dosage and density of labelled herbicide on entry, translocation, root exudates and 2) to assess the half-life of herbicide in different sources of water.

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MATERIALS AND METHODS

Young water hyacinth was allowed to float in plastic pots of size 30 cm diameter with 30 cm depth and one litre mark level indicator for 30 days. Daily water loss due to evapo-transpiration was assessed and Hebbal Lake pond water was added to maintain one liter level at 9:00 h.

Preparation of ^{14}C-glyphosate

^{14}C-methyl labeled glyphosate with specific activity of 0.01 mci/mole was procured from Sigma Aldrich and mixed with 1 µl 2000 ppm non radioactive glyphosate (Roundup 41 SL). From this stock, to 10 µl of ^{14}C-glyphosate, 1 µl of 1.64 kg/ha Roundup (10 µl/l) was mixed. Similarly, 20 µl of ^{14}C-glyphosate stock µlof 3.28 kg/ha of glyphosate (20 ml/l) was mixed.

^{14}C-glyphosate -x (1.64 kg/ha –recommended)
^{14}C-glyphosate -2x (3.28 kg/ha–twice recommended)

Preparation of ^{14}C-2,4-D

^{14}C-carboxyl labeled solid 2,4-D with specific activity 92 mci/mmol was dissolved in 15 µlethanol. Then volume was make up to 1.5 ml with 5000 ppm of 2,4-D (non-radioactive) sodium salt (80%). From this stock, to 10 µl of labeled 2,4-D, 1 µl of 3.2 kg/ha (10 g/l) 2,4-D and to 20 µl of labeled 2,4-D 1 µl of 6.4 kg/ha of 2,4-D (20 g/l) was added to obtain different treatment.

^{14}C-2,4-D -x (3.2 kg/ha)

^{14}C- 2,4-D -2x (6.4 kg/ha)

These four treatments were given to 30 days old water hyacinth with five replications. For x and 2x dosage, 5 and 10 drops of 0.2 µl were placed on fully expanded young leaf. Thus varied drop density and concentration of herbicide per drop affect was assessed on dried residue, entry into cuticle, the plant system and exudates of herbicide from root.

Measurement of radioactivity in root exudates

At regular interval of two days water sample of one ml was drawn near the root zones of water hyacinth to assess the radioactivity that has moved out of plant system.

Measurement of radioactivity

After 10 days, plants were harvested and separated into different plant parts *viz.*, 1) washing the fed spot (dried out residue on the cuticle); 2) fed spot of the fed leaf (partitioning coefficient between different cuticle layers and desorption from cuticle); 3) translocation to other portion of the fed leaf (within fed leaf); 4) other leaves and 5) root. Aqueous extract of plant parts using pestle and mortar, volume was made up using water and acetone used as washing material between samples. Radio-activities (counts per minute -CPM) was measured using Liquid Scintillation Counter (LSC) of make Wallac- Model 1409 with scintillation liquid of 3 ml with or without plant (10 µl) or water (50µl) sample and eq (1). Radioactivity was expressed in CPM/100 mg of organ weight, except dried out residue CPM/10 ml washed water.

$$\text{CPM} = (\text{R/aliquot}) \times \text{volume made up} \text{ ——— } (1)$$

R indicates radioactivity of sample after correction for blank was multiplied by a factor (eq.2) to give correction for LSC dilution factor. The LSC was unable to detect over lapping of radiation within a microsecond which occurs due to high concentration of radioactive compound present.

$$\text{LSC dilution factor correction} = 4E\text{-}12x^2 + 4E\text{-}06x + 0.054 \text{ — } (2)$$

Where x indicated observed activity CPM of the sample.

Measurement of radioactivity in water residue

Pond water might contain microbes compared to normal water to degrade the herbicides. Herbicide (2x) was added to the beaker containing 25 ml of normal or pond water with five replications. The initial CPM/25 ml of ^{14}C-glyphosate and ^{14}C-2,4-D were 1504 and 1214, respectively. At regular interval of two days for ten days, later on at 5 days intervals, samples of one ml were drawn and activity was recorded for 20 days. Whenever samples were drawn, one ml of normal or pond water was added. Per day, 3.2 ml of water was evaporated and thus activity of herbicide can be concentrated. To compensate the radioactivity measured was given a correction factor (CF) using the following equation (3)

$$CF = (Q/25)/ 0.025 \text{ ——— } (3)$$

Where, Q indicated quantity of water remaining in the beaker on the day of radioactivity measured, 25 is the quantity of water initially present and 25µl is the aliquot taken for the radioactivity measurement. Treatment was replicated five times and data were statistically analyzed using RBD design.

Half life and persistence of herbicides in water

Regression between periodic herbicide mean radio-activity in water against time was computed. The model performance was judged by coefficient of determination (R^2) and residue sum of square (RSS = S (observed-predicted response) 2) observed that first order exponential equation fitted well (eq 4) with high R^2 and low RSS values (0.1-0.45). However, forcing a=Y showed low R^2, poor fit still, half life was computed using a=Y in (eq 5).

$$Y = a\, e^{-bt} \text{ ————— } (4)$$

$$\text{Half life (days)} = [\ln (Y) - \ln(Y/2)]/b \text{ —————— } (5)$$

Where Y/2 is half of initial activity of respective herbicides, “a” indicates the Y axis intercept and “b” denotes slop (rate of degradation) of best fit regression curve. Statistical analysis of all data was carried out using RBD with five replications.

RESULTS AND DISCUSSION

Increase drop density and concentration 2x of both herbicides per drop per fed spot enhanced the dried out residue significantly on the cuticle than recommended (x) (Table 1). The per cent dried out reside increased to 91.2 and 79.5 for glyphosate and 2,4-D than x dose 67.2 and 67.9, respectively. Radioactivity in fed spot showed significant penetration of herbicide into the cuticle in 2,4-D but not for glyphosate, indicating 2,4-D movement across cuticle layers block than glyphosate. Entry of herbicide into cuticle depends on diffusibility of herbicide from drop, and mobility of herbicide across different layers

Table 1. Effect of dosage of radioactive herbicide (CPM/100 mg) on entry and translocation in water hyacinth (10 days after feeding)

Treatment	Dried residue	Fed spot	Rest of fed leaf	Other leaves	Root	Water	Total
^{14}C-glyphosate x	2057 (45.4^{c})	320(17.8^{c})	407(20.18^{a})	87 (9.32)	155 (12.45^{a})	35^{ab}	3061 (55.32^{d})
^{14}C-glyphosate 2x	6166 (78.5^{a})	334(18.3^{c})	345(18.55^{a})	111 (10.54)	62 (7.88^{bc})	44^{ab}	7062 (84.0^{b})
^{14}C- 2,4-D x	3368 (57.9^{b})	1186(34.4^{b})	114(11.03^{b})	173 (12.87)	85 (9.23^{b})	29^{b}	4955 (70.39$^{c)}$
^{14}C-2,4-D 2x	6546 (80.9^{a})	2187(45.9^{a})	98 (9.85^{b})	147 (11.8)	52 (7.20^{c})	55^{a}	9085 (95.3^{a})
LSD (P=0.05)	(6.03)	(10.53)	(3.12)	(NS)	(1.44)	19.3	(7.11)

Figures in the parentheses are square root transformed values

*Superscripts indicate Duncan's range test, treatments with same alphabet are non-significant

of cuticle by partitioning coefficients, for this availability of free herbicide molecule plays an important role. Herbicides forms complex with divalent cation *viz.*, Ca^{++}, Mg^{++}, Fe^{++} present in hard water at improper pH spray solution or 2,4-D bound to epoxides and glyphosate with Ca^{++} present in the cuticle layers, thus free herbicide molecules gets reduced and antagonize the herbicide movement across cuticle. Further, divalent cations deposits as dried out residue from glandular trichome exudates by the process of guttation was reported (Carole and Philip 1982). Alkaline pH (6 or 10) ionizes the herbicides having carboxylic (COOH) in the drop and form herbicide-cation complex thus free herbicide molecules are not available for cuticle penetration (Patrick and Duane 1984).

Higher mobility of glyphosate from fed spot to rest of the fed leaf in both concentrations than 2,4-D was observed suggesting that glyphosate was more translocation type than 2,4-D. Translocation from fed leaf to other leaves was not affected by increased dosage of herbicides. However, in root 2x of herbicides had significantly less herbicide than x dose for both herbicides. Water near to the root zone recorded significantly more 2,4-D but the per cent of total in water due to root exudates ranged 0.4 to 1.1. This suggested that much of the herbicide remained as dried out residue with little or negligible as root exudates.

Root exudates of herbicide to the water near the root zone increased in 2x significantly after 8 days (Table 2) but still the root exudates was 1.1 per cent of total activity recovered. Thus herbicides remain in water hyacinth and do not pollute the water body, therefore herbicides toxicity to fishes were unlikely by foliar applied herbicide.

Residue of ^{14}C-herbicide in normal or pond water indicate drastically reduction of both herbicide in pond water than normal water (Fig. 1). Pond water infested with water hyacinth microbes which degrade the herbicide faster than normal water. Accidental drift of herbicides spray droplet into the water lost its effect within 5 days. Half-life of glyphosate and 2,4-D was around 5.2 days in the pond water whereas it was around 8 and 12 days for glyphosate and 2,4-D in normal water (Table 3). Kirkwood (1979) suggested high adsorption of glyphosate to soil sediment (major sink) which cause slow degradation by microbes (low population in soil than in water). Half life of glyphosate may be >35 days, but it was 1.5 -11.2 days in water (Newton *et al.* 1994). Unlike, 2,4-Dichlorophenol degraded product of 2,4-D which is 15 times more toxic than 2,4-D (www.24d.org), degraded product of glyphosate seemed to be non toxic to fish (U.S. EPA RED 2005). Much of the herbicide gets remained in water hyacinth and accidental drift of the herbicide into the water will be degraded by five days. Thus it was inferred that mortality

Table 2. Effect of dosage of radioactive herbicide (CPM/µl) on periodic herbicide root exudates into water from water hyacinth

Treatment	Days after treatment				
	2	4	6	8	10
Glyphosate x	25.4	27.0	30.4	35.6^{b}	38.7^{b}
Glyphosate 2x	34.9	36.4	36.7	44.0^{ab}	60.6^{a}
2,4-D x	20.6	23.9	29.0	29.3^{b}	35.4^{b}
2,4-D 2x	29.0	31.0	40.7	53.5^{a}	54.6^{ab}
LSD (P=0.05)	NS	NS	NS	17.8	19.3

*Superscripts indicate Duncan's range test, treatments with same alphabet are non-significant

Table 3. Half-life of ^{14}C-herbicide in water (bore well or pond) as estimated by first order exponential equation

Treatment	Type of water used	Exponential equation	R^2	Half-life (in days)
^{14}C-glyphosate	Normal water	$1504e^{-0.09t}$	0.671	7.7
	Pond water	$1504e^{-0.13t}$	0.672	5.3
^{14}C-2,4-D	Normal water	$1214e^{-0.06t}$	0.822	11.5
	Pond water	$1214e^{-0.13t}$	0.130	5.3

Normal water- tube well water of Main Research Station, Hebbal. Pond water- water from *Eichhornia* infested Hebbal Lake

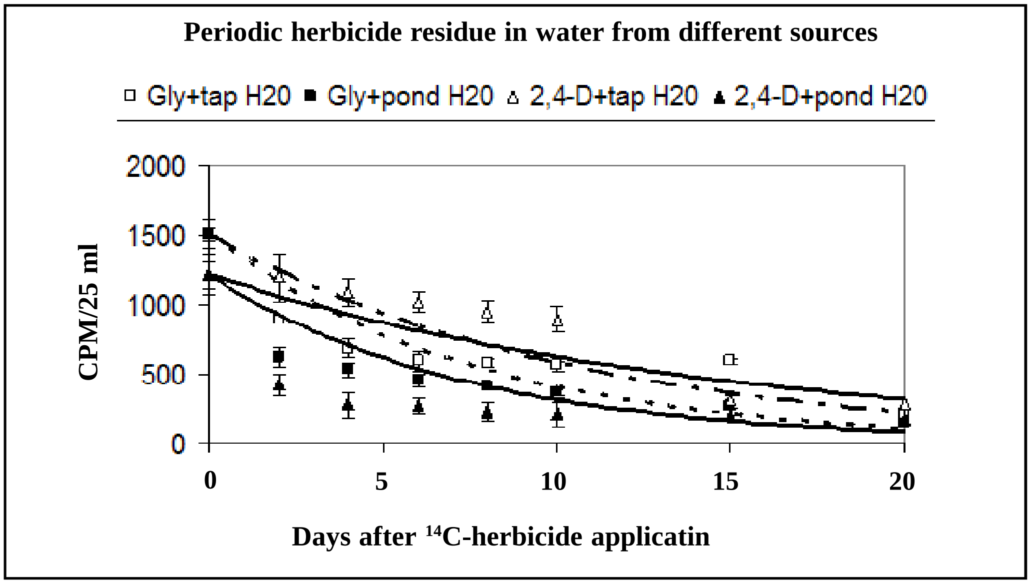

Fig. 1. Radioactive herbicide (2x) decay in different sources of water. Solid line represents 2,4-D and dotted line indicates glyphosate degradation pattern. Error bar indicates replication variations

of the fish in herbicide treated pond is not due to herbicide toxicity but decaying plant material which depletes the oxygen in water, therefore instead of increasing the dose of herbicide the good adjuvants should be used to enhance the penetration of herbicide.

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Evaluation of bioefficacy of clodinafop-propargyl + metsulfuron-methyl against weeds in wheat

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ABSTRACT

A field experiment was conducted at Pantnagar during winter season 2005-06 and 2006-07 to study effect of rates of herbicide mixture clodinafop-propargyl 15% + metsulfuron-methyl 1% (UPH-206) for control of mixed weed flora in wheat (*Triticum aestivum* L.). Grassy weeds such as *Phalaris minor, Avena fatua* and broad-leaved weeds, *viz., Chenopodium album, Melilotus* spp., *Medicago denticulata, Vicia sativa, Rumex* spp., *Anagallis arvensis, Coronopus didymus, Lathyrus aphaca* and *Polygonum plebejum* were effectively controlled by application of UPH-206 500 g product/ha. The highest grain yield (4.17 t/ha) of wheat was also obtained with the post-emergence application of UPH-206 500 g product/ha being at par with UPH-206 400 g product/ha, and hand weeding at 35 and 55 DAS, but significantly higher than sulfosulfuron, clodinafop and isoproturon at recommended rates. No residual effect of UPH 206 at any of doses tested was obtained on succeeding crops of blackgram and maize.

Key words: Clodinafop-propargyl, Metsulfuron-methyl, UPH-206, Wheat

In North-Western part of India, wheat is mainly infested with *Phalaris minor, Avena ludoviciana, Chenopodium album, Medicago denticulata, Melilotus alba, Melilotus indica, Fumaria parviflora, Vicia hirsuta, Vicia sativa, Coronopus didymus* and *Rumex acetocella*. Herbicides have provided effective control of weeds; however, increased use of isoproturon led to the evolution of resistant *Phalaris minor* Retz. biotypes and shift in weed flora (Malik and Singh 1993). To overcome this problem, fenoxaprop-p-ethyl, sufosulfuron and clodinafop-propargyl have been recommended (Chhokar and Malik 2002). Fenoxaprop-p-ethyl and clodinafop-propargyl are specific to *P. minor* and *A. ludoviciana* but are ineffective against broad-leaved weeds. Continuous use of these herbicides have resulted in tremendous increase in density of broad-leaved species like *Rumex acetocella, M. denticulata, C. album, Melilotus* spp., *Vicia* spp., *F. parviflora* and *C. didymus*. So there is a need to evaluate alternative herbicides with different mode of action for the control of complex weed flora in wheat. Present experiment was carried out to assess the relative bio-efficacy of new herbicide molecule clodinafop-propargyl + metsulfuron-methyl.

MATERIALS AND METHODS

A field trial was conducted during winter season 2005-06 and 2006-07 at Pantnagar to evaluate the bio-efficacy of a ready-mix combination of clodinafop-propargyl 15% + metsulfuron-methyl 1% (UPH-206), which has been registered with trade name Vesta. The soil of the experiment field was loam in texture (38.4% sand, 45.0% silt and 16.6% clay), pH 7.5, medium in organic C (0.58%), high in available P (35.6 kg P/ha) and medium in available K (164.5 kg K/ha). Wheat variety '*UP-2425*' was sown on 21 December, 2005 and 2 December, 2006 using seed rate of 100 kg/ha in rows 20 cm apart. Recommended package of practices were followed to raise the crop. Different doses of UPH-206 with surfactant were compared with isoproturon, sulfosulfuron, clodinafop-propargyl and metsulfuron-methyl at their recommended rates along with two manual weedings at 35 and 55 days after sowing (DAS) and weedy check (Table 1). Nine treatments were replicated thrice in randomized block design. All the herbicides were applied at 35 DAS, using a knapsack sprayer at a spray volume of 375 litres of water/ha in case of UPH-206, clodinafop and sulfosulfuron, and 500 litres of water/ha for isoproturon and metsulfuron-methyl. Data on density and dry matter accumulation of weeds was taken at 60 DAS, and subjected to $\sqrt{(x+1)}$ transformation before statistical analyses. To study the phytotoxic effect, visual rating on the scale of 0-10 for UPH-206 applied 400 and 800 g product/ha was made.

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RESULTS AND DISCUSSION

Grassy weeds *viz., Phalaris minor* and *Avena fatua* constituted 62.4% of total weed population, while the remaining were broad leaved species *viz., Chenopodium album, Melilotus* spp., *Medicago denticulata, Vicia sativa, Rumex* spp., *Anagallis arvensis, Coronopus didymus, Lathyrus aphaca* and *Polygonum plebejum*. Weed management practices significantly reduced the population and dry matter of weeds recorded at 60 DAS as compared to weedy check (Table 1). Application of UPH-206 500 g product/ha with surfactant was most effective and provided 97.3% control of grassy weeds. This was followed by UPH-206 400 g product/ha, two manual weedings at 35 and 55 DAS, and clodinafop-propargyl 15% WP 400 g/ha. Application of sulfosulfuron 75% WG at 33.3 g/ha or isoproturon 75% WP 1333.3 g/ha was not found so effective for the control of grassy weeds. Punia *et al.* (2008)

Table 1. Effect of clodinafop-propargyl + metsulfuron-methyl and other herbicides on density of weeds in wheat

Treatment	Dose		Surfactant (ml/ha)	Weed population/m^2 at 60 DAS					
				Grassy weeds			Broad leaved weeds		
	g/ha	Product (g/ha)		2005-06	2006-07	Mean	2005-06	2006-07	Mean
Isoproturon	1,000	1333.3	-	6.0 (25.0)	10.8 (95.3)	8.8 (60.2)	7.1 (37.0)	8.6 (57.3)	7.9 (47.2)
Sulfosulfuron + surfactant	25	33.3	1250	4.6 (13.0)	6.0 (25.3)	5.4 (19.2)	6.7 (32.0)	5.5 (20.3)	6.1 (26.2)
Clodinafop-propargyl	60	400	-	3.7 (7.0)	4.8 (14.7)	4.3 (10.9)	11.8 (117.0)	13.6 (159.7)	12.8 (138.4)
Metsulfuron-methyl + surfactant	4	20	625	15.5 (211.0)	12.4 (129.3)	14.0 (170.1)	4.3 (11.0)	4.1 (9.3)	4.2 (10.2)
UPH-206	45+3	300	1250	3.2 (5.0)	5.2 (17.3)	4.3 (11.2)	6.4 (29.0)	4.8 (14.7)	5.7 (21.9)
UPH-206	60+4	400	1250	2.4 (2.0)	4.5 (12.3)	3.7 (7.1)	3.5 (6.0)	3.9 (8.7)	3.7 (7.4)
UPH-206	75+5	500	1250	2.0 (1.0)	4.4 (11.7)	3.5 (6.4)	3.0 (4.0)	3.3 (5.3)	3.2 (4.7)
Hand weedings	-	-	-	1.0 (0.0)	5.0 (15.7)	3.8 (7.8)	3.2 (5.0)	2.8 (3.3)	3.0 (4.2)
Weedy check	-	-	-	15.7 (215.00)	17.0 (255.0)	16.3 (235.0)	11.7 (115.0)	13.4 (152.7)	12.6 (133.9)
LSD (P=0.05)				2.0	1.9	0.8	0.2	1.5	1.3

* Data in parentheses are transformed values $\sqrt{(x+1)}$

Table 2. Effect of clodinafop-propargyl + metsulfuron-methyl and other herbicides on weed dry weight and grain yield of wheat

Treatment	Dose		Surfactant (ml/ha)	Total weed dry weight (g/m^2) at 60 DAS			Grain yield (t/ha)		
	g/ha	Product (g or ml/ha)		2005-06	2006-07	Mean	2005-06	2006-07	Mean
Isoproturon	1,000	1333.3	-	6.9 (34.8)	8.6(57.0)	7.8(45.9)	3.80	3.21	3.50
Sulfosulfuron + surfactant	25	33.3	1250	5.1 (17.0)	5.5(20.2)	5.3(18.6)	3.93	3.92	3.92
Clodinafop-propargyl	60	400	-	9.5 (72.5)	10.5 (89.3)	10.0(80.9)	3.40	3.67	3.53
Metsulfuron-methyl + surfactant	4	20	625	14.0(167.8)	4.8(14.4)	14.2 (175.0)	2.72	3.43	3.08
UPH-206	45+3	300	1250	4.5(12.0)	3.9(8.5)	4.6(13.2)	3.98	3.71	3.85
UPH-206	60+4	400	1250	3.7 (7.3)	3.9 (8.5)	3.8(7.9)	4.08	4.22	4.15
UPH-206	75+5	500	1250	2.8(3.2)	2.4 (2.0)	3.1(4.25)	4.05	4.29	4.17
Hand weedings	-	-	-	1.0 (0.0)	2.4(2.0)	2.0 (1.0)	4.09	4.15	4.12
Weedy check	-	-	-	16.1 (228.0)	15.2(201.3)	15.7(214.1)	1.53	2.33	1.93
LSD (P=0.05)				1.5	1.9	1.5	0.28	0.33	0.24

*Data in parentheses are transformed values $\sqrt{(x+1)}$

also reported excellent control of grassy weeds in wheat with the application of UPH-206 400 and 500 g product/ha. Application of metsulfuron-methyl 20 g/ha was not found effective against grassy weeds in wheat.

The efficacy of the herbicides on broad-leaved weeds indicated that UPH-206 500 g product/ha resulted in their excellent control (96.5%). It was found at par with UPH-206 400 g product/ha, metsulfuron-methyl 20% WP at 20 g/ha. Excellent control of complex weed flora in wheat was observed with the tank-mix application of clodinafop + metsulfuron methyl (15:1 ratio) at 60 g/ha (Punia *et al.* 2004). On the other hand, application of clodinafop-propargyl 15% WP at 60 g/ha showed no efficacy against broad-leaved weeds. The lowest dry weight of total weeds was recorded with two manual weedings at 35 and 55 DAS, being at par with the application of UPH-206 500 g product/ha. Among the herbicide treatments, UPH-206 500 g product/ha recorded minimum weed dry weight (4.1 g/ha), which was followed by UPH-206 400 g product/ha.

Unchecked weed growth reduced grain yield of wheat by 54% when compared with UPH-206 500 g product/ha. Maximum yield (4.17 t/ha) was recorded from UPH-206 500 g product/ha, which was followed by UPH-206 at 400 g product/ha (4.15 t/ha) and manual weeding at 33 and 35 DAS (4.12 t/ha). Higher grain yield with UPH-206 500 g product/ha was due to more number of effective tillers and number of grains/ear. No phytotoxicity symptoms *viz.*, yellowing, scorching, necrosis, epinasty and hyponasty were observed in case of UPH-206 even at higher dose of 800 g product/ha during entire wheat season. Further, no residual effect of UPH-206 applied in wheat even at 800 g product/ha on germination of succeeding crops *viz.*, urdbean and maize was observed. Germination and growth of succeeding crops in plots treated with UPH-206 400 and 800 g product/ha were similar as untreated control plots.

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Butachlor dissipation in rice grown soil and its residues in grain

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ABSTRACT

A field experiment was conducted in an Alfisol to study the degradation of butachlor and its residues in paddy grain during *Rabi* and *Kharif* seasons of 2007-08 at College Farm, College of Agriculture, Rajendranagar. Butachlor dissipated with half life varying from 12.5 to 21.5 days when applied at the rate of 1.0 and 2.0 kg/ha under with and without organic manures conditions. The observed half life values were lower for lower dose of applied herbicide as compared to higher dose and the field half life of butachlor was more under without organic manures as compared to organic manures applied plots. Residues of butachlor in field soil were analysed by using gas chromatograph and 100% dissipation of butachlor was observed at the time of harvest of crop. Very low levels of residues were detected in rice grain below the maximum residue limit of 0.5 mg/kg. Therefore, application of butachlor in paddy for weed management can be considered safe from the point of consumption of grain.

Key words: Butachlor, Dissipation, Half life, Residues, Rice

The usage of pesticides in agriculture plays a vital role to increase the agriculture production. The indiscriminative use of pesticide has resulted in the presence of pesticide residues in different components such as agriculture commodities, soil, water, milk *etc*. which pose health hazards to human beings and animals. Among all the chemicals, use of herbicides for the control of weeds has become imperative especially in the irrigated agriculture for a wide variety of reasons like non availability of labours, high labour cost, unfavorable climatic conditions for weeding *etc*. However recommendations on chemical weed control remain incomplete if the data of toxic herbicidal residues are not provided. It is therefore, essential to undertake studies on the fate and behavior of herbicides in different crops from both environmental and agronomic considerations. Butachlor used as pre-emergence herbicide in rice for controlling grassy as well as broad leaved weeds. Information on dissipation and residues of butachlor in rice and role of different organic manures on butachlor dissipation was not available in Andhra Pradesh agro climatic conditions. Hence, present study was conducted to know the residue accumulation and dissipation of butachlor in rice.

MATERIALS AND METHODS

A field experiment was conducted on an Alfisol at College Farm, College of Agriculture, Rajendranagar for *Rabi* and *Kharif* seasons during 2007-08. Rice crop was grown in split plot design with four main (M1-FYM 10 t/ha, M2-Poultry manure 2 t/ha, M3-Vermicompost 5 t/ha and M4: Unweeded check) and two sub-treatments (T1-Pre-emergence application of butachlor 1 kg/ha, T2-Pre-emergence application of butachlor 2 kg/ha). The experimental details were as follows: F1T1-Butachlor 1 kg/ha + FYM 10 t/ha; F1T2-Butachlor 2 kg/ha + FYM 10 t/ha, P1T1- Butachlor 1 kg/ha + poultry manure 2 t/ha, P1T2-Butachlor 2 kg/ha + poultry manure 2 t/ha, V1T1-Butachlor 1 kg/ha + vermicompost 5 t/ha, V1T2-Butachlor 2 kg/ha + vermicompost 5 t/ha, C1T1-Unweeded check 1 kg/ha and C1T2-Unweeded check 2 kg/ha. The residues of the herbicide were estimated in surface soil up to harvest in different intervals. Residues of butachlor were analyzed by gas chromatography using Electron Capture Detector. The recovery studies were carried out at 2 ppm, 1 ppm and 0.5 ppm concentrations. Percent recovery of butachlor varied from 85 to 94 per cent.

Sample collection and preparation

Soil samples were collected from 6-7 spots in each plot on 0 (2 hours after application), 15, 30, 45 and 60 days after application. Soils were collected from control plots and treated plots and the samples were mixed thoroughly, air dried, ground and passed through a 2 mm sieve. A representative 1 kg sample was taken by quartering method for estimating herbicide residues. For edible parts, plants were collected randomly from each plot at harvest time. Samples kept in deep freezer were taken out at the time of analysis and brought to room temperature.

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A stock solution (1.0 mg/ml) was prepared for butachlor in acetone. A 100 microgram per ml fortification standard was prepared by taking a 5 ml aliquot in 50 ml volumetric flask with acetone. Further dilutions were made to make a 10 and 1 microgram per ml solution. Fortification trials were conducted with 1.0 and 2.0 ppm solutions and all stock, fortification and internal standard solutions were stored at -20^{0}C in the deep freezer until use.

The reference standard of butachlor was used for quantification, recovery and determination of retention time of the herbicide. The soil and plant edible part samples were collected from fields where no herbicide was applied. The samples were sieved/ground and the required quantity of the technical grade butachlor was added to 50 g soil/20 g plant edible part sample. All samples were replicated twice. The soil and plant edible part samples were fortified with 1 ppm and 2 ppm solutions. Control as well as blank samples were maintained to check for the contamination and interferences.

A representative 10 g sieved soil/5 g edible parts was extracted with 150 ml of acetone:hexane. The samples were kept overnight and filtered through buchner funnel and again the samples were rinsed with another 50 ml of acetone: hexane and the extract was evaporated, mixed with 0.3 g activated charcoal, 0.3 g florosil, 10 g anhydrous sodium sulphate and packed in the glass column. Column was eluted with 100 ml of mixture of acetone: hexane (1:9), Elutent was evaporated to dryness in a rotary evaporator at 45^{o}C and residue is re dissolved in 5 ml of n-hexane.

Preparation of standard solutions

Standard solution of 100 ppm butachlor was prepared by dissolving 115.1 mg of technical grade herbicide in 100 ml of methanol. From this 100 ppm solution, 1 ppm standard solution was prepared and injected the sample to GC. Butachlor eluted as a peak at 11.88 minutes. GC parameters were as follows:

Name of the gas chromatograph	Shimadzu GC 2010
Name of the column	ZB-5,30 m length ID 0.53 mm, film thickness 1.50 um
Carrier gas used	Nitrogen
Carrier gas flow	53.6 ml/minute
Column temp/over temp.	220
Injector temperature	240
Injector split ratio	1:10
Detector	Electron capture detector (ECD) with Ni 63
Detector temperature	260
Make up gas flow	60 ml/minute
Retention time	11.88 min

Clean up and estimation

To a chromatographic column (2 mm I.D) 4 g of florosil followed by 10 g of anhydrous sodium sulphate was added. The concentrated extract was diluted to 10 ml with 10% acetone in hexane. Then the solution was transferred to florosil column. Container was rinsed with hexane and transferred to column. The column was eluted with about 5 ml/min and florosil eluate was concentrated to 1 ml. The extract was used for the determination of herbicide residues by GLC on ECD. One micro liter of reference standard solution of herbicide was injected. The peaks by their retention time were identified and the peak area was measured. The amount of residues of herbicide was calculated with the following formula:

Residues in mg/kg =

$$\frac{\text{Area of sample}}{\text{Area of standard}} \times \frac{\mu\text{l std. injected}}{\mu\text{l sample injected}} \times \frac{\text{final volume}}{\text{wt. of the sample}} \times \text{Recovery factor}$$

RESULTS AND DISCUSSION

Dissipation of butachlor during *Rabi* season

Initial deposits in soil were estimated to be 0.768 and 0.692 mg/kg at 1 and 2 kg/ha herbicide in unweeded check. It was observed that with the passage of time the residue deposits were reduced in all the treatments, irrespective of herbicide dose and manure source. In case of higher dose of herbicide application *i.e* 2 kg/ha, herbicide residues were slightly increased than lower dose of herbicide application *i.e* 1 kg/ha. Comparatively faster rate of dissipation was observed in manure added plots than control plot. Almost 99% of the applied herbicide was dissipated by harvest time. In case of low levels of herbicide application *i.e* 1 kg/ha within the first 15 d of application, maximum of 45% of the initial amount was lost and on the 45 d of application chemical almost dissipated. The degradation followed the first order kinetics and at different doses of butachlor application, the half life values ranged from 12.54 to 21.5.

Dissipation of butachlor during *Kharif* season

Initial deposits detected were 0.555, 0.598, 0.732 and 0.862 mg/kg in farmyard manure, poultry manure, vermicompost applied plots and unweeded check at 1 kg/ha herbicide and 0.898, 0.754, 0.698 and 0.734 mg/kg at application of higher dose of 2 kg/ha, respectively. At harvest, almost 100% of initial deposit of butachlor was dissipated and no residues were detected with a half life of 12.54 days at 1 kg/ha herbicide application + FYM 10 t/ha, however these half life values were slightly increased to 14.33 and 17.74 d for poultry manure and vermicompost at lower dose of herbicide of 1 kg/ha. The estimated residues of herbicides was decreased from 0 days after sowing to harvest. In unweeded check, the half life values were 21.5 and 17.70 d at 1 and 2 kg/ha, respectively. Higher dose of herbicide concentration increased half life in both the cases. Similar results were also reported by kalpana *et al*.(1999).

In general, residue deposits were more during *Rabi* season (first season) than *Kharif* (second season), which might be due to physical parameters like temperature, wind velocity and moisture level. Similar observations were also reported by Kalpana *et al*. (1999) for the dissipation of pendimethalin and fluchloralin in soil, Guha *et al*. (1992) for the dissipation of fluchloralin in *Kharif* rice under West Bengal agriculture conditions, Goutam and Ashim

Table 1. Residues (mg/kg) and dissipation of butachlor in rice grown soil

Treatment	Days after application					Half-life
	0	15	30	45	60	
Butachlor 1 kg/ha + FYM 10 t/ha						
Rabi	0.642	0.309	0.179	0.065	0.006	
Kharif	0.555	0.353	0.208	0.086	0.004	12.54 days
Mean	0.598	0.331	0.193	0.075	0.005	
	Y= 0.2584–0.024x					
Butachlor 2 kg/ha + FYM 10 t/ha						
Rabi	0.885	0.521	0.233	0.104	0.018	
Kharif	0.898	0.462	0.304	0.112	0.012	18.81 days
Mean	0.891	0.491	0.268	0.108	0.015	
	Y= 0.3541–0.016 x					
Butachlor 1 kg/ha + poultry manure 2 t/ha						
Rabi	0.634	0.420	0.223	0.085	0.005	
Kharif	0.598	0.352	0.241	0.108	0.008	
Mean	0.616	0.386	0.232	0.096	0.006	14.33 days
	Y=0.4258–0.021x					
Butachlor 2 kg/ha + poultry manure 2 t/ha						
Rabi	0.823	0.461	0.261	0.106	0.007	
Kharif	0.754	0.306	0.218	0.086	0.006	15.84 days
Mean	0.788	0.383	0.239	0.096	0.011	
	Y=0.5841–0.019x					
Butachlor 1 kg/ha + vermicompost 5 t/ha						
Rabi	0.754	0.381	0.208	0.146	0.018	
Kharif	0.732	0.442	0.253	0.123	0.012	17.70 days
Mean	0.743	0.411	0.230	0.134	0.015	
	Y= 0.3569–0.017x					
Butachlor 2 kg/ha + vermicompost 5 t/ha						
Rabi	0.746	0.563	0.286	0.166	0.012	
Kharif	0.698	0.452	0.234	0.122	0.013	18.81 days
Mean	0.722	0.507	0.260	0.144	0.012	
	Y= 0.5427–0.016x					
Unweeded check 1kg/ha						
Rabi	0.768	0.623	0.242	0.112	0.008	
Kharif	0.862	0.692	0.356	0.218	0.012	
Mean	0.815	0.657	0.299	0.165	0.010	21.5 days
	Y=0.3148–0.014x					
Unweeded check 2 kg/ha						
Rabi	0.692	0.522	0.236	0.120	0.019	
Kharif	0.734	0.568	0.208	0.106	0.014	17.70 days
Mean	0.713	0.545	0.222	0.113	0.016	
	Y=0.4625–0.017x					

Table 2. Residues of butachlor in rice grain (mg/kg)

Treatment	Residues in grain (*Rabi*)	Residues in grain (*Kharif*)
F1T1: Butachlor 1 kg/ha + FYM 10 t/ha	0.0042	0.0051
F1T2: Butachlor 2 kg/ha + FYM 10 t/ha	0.0063	0.0074
P1T1: Butachlor1 kg/ha + poultry manure 2 t/ha	0.0054	0.0048
P1T2: Butachlor 2 kg/ha + poultry manure 2 t/ha	0.0078	0.0095
V1T1: Butachlor 1 kg/ha + vermicompost 5 t/ha	0.0029	0.0035
V1T2: Butachlor 2 kg/ha + vermicompost 5 t/ha	0.0094	0.0074
C1T1: Unweeded check	0.0015	0.0021
C1T2:Unweeded check	0.0029	0.0032
MRL Values	0.05	0.05

(1994) for residue and persistence of pendimethalin in groundnut. Photo-decomposition might be another factor for the loss of these herbicides from soil due to high temperatures during *Rabi* as compared to *Kharif* season (Guha *et al*. 1992, Abhram *et al*. 1987, Savage and Jordan 1980).

Butachlor residues in rice grain

The residues of butachlor in paddy grain were below maximum residual limits (Table 2). Maximum residue value of 0.0095 mg/kg was observed at 2 kg/ha of herbicide (with poultry manure) during *Kharif* season. However, in both seasons and in all the treatments, the detected residues were below maximum residue limits of 0.05 µg/g (The Pesticide Chemical News Guide 1985). As a part of applied herbicides were adsorbed to soil, a part may be leached down to deeper layers and the initial deposits of butachlor were dissipated at the time of harvest of the crop may contributed to lower levels of herbicides in rice grain. (Annual reports of AICRP on Weed Control 2001).

Residues of butachlor in field soil were also analyzed at the time of harvest of crop by using gas chromatograph and 100% dissipation of butachlor was observed. The observed half life values were lower for lower dose of applied herbicide as compared to higher dose. In rice grain, the residues were below the maximum residue limits (0.05 µg/g). Therefore, it may be concluded that pre-emergence application of butachlor in rice for weed management could be considered safe from the point of consumption of rice at the harvest.

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Integrated weed management in onion

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ABSTRACT

A field experiment was carried out for two consecutive years during *Kharif* seasons of 2010 and 2011 to find out practically convenient and economically feasible weed management practice in onion at breeder seed production farm in Mahatma Phule Krishi Vidyapeeth, Rahuri. Different combinations of hand weeding with application of Pendimethalin 1.0 kg/ha (pre-planting) and oxyfluorfen 0.250 kg/ha (post-emergence) were used in onion variety '*Baswant-780*'. Weed free check treatment (three hand weeding at 20, 40 and 60 DAS) recorded significantly lowest weed density, dry weight of weed and higher weed control efficiency. All the growth attributes of onion *viz*., plant height, neck thickness, bulb weight and bulb diameter were recorded maximum in weed free. This treatment also recorded highest bulb yield and gross monetary return per hectare, however maximum B:C ratio was observed in treatment pendimethalin 1.0 kg/ha (PP)+ Oxyfluorfen 0.250 kg/ha (POE)+ One hand wedding at 40 DAS.

Key words: Integrated weed management, Oxyfluorfen, Pendimethalin, Soybean

Onion (*Allium cepa* L.) is one of the most important commercial vegetable crops grown all over the world. In India onion occupies about 1.06 million hectare area having 15.12 million metric tons of production and average productivity of 14.2 tons per hectare (Anonymous 2011). The most important onion growing states are Maharashtra, Tamil Nadu, Andhra Pradesh, Bihar and Punjab. Onion is slow growing, shallow rooted crop with narrow, upright leaves and non branching habit. Due to this type of growing habit, onion crop cannot compete well with weeds. In addition to this, frequent irrigation water and fertilizer application allows for successive flushes of weeds in onion. Yield loss due to weed infestation in onion has been recorded to the tune of 40 to 80% (Channapagoudar and Biradar 2007). The conventional methods of weed control (hoeing and weeding) are laborious, expensive and insufficient. On the other hand, use of herbicides alone does not prove effective for weed control because of their selectivity. Hence an attempt was made to find out the appropriate combination of cultural and chemical weed management practices for weed control in onion which is practically effective and economically feasible for farmers.

MARERIALS AND METHODS

An experiment was conducted during *Kharif* season of 2010 and 2011 at Breeder Seed Production Farm, Seed Cell Unit, MPKV, Rahuri. The soil of experimental field was medium black with slightly saline nature. The experiment was laid out in randomized block design with three replications and nine treatments, *viz.,* weed free check (3 hand weeding at 20, 40 and 60 DAS), one hand wedding at 20 DAS, pendimethalin 1.0 kg/ha (PP), oxyfluorfen 0.250 kg/ha (POE), pendimethalin 1.0 kg/ha (PP)+ one hand weeding at 40 DAS, oxyfluorfen 0.250 kg/ha (POE)+ one hand weeding at 40 DAS, pendimethalin 1.0 kg/ha (PP)+ oxyfluorfen 0.250 kg/ha (POE), pendimethalin 1.0 kg/ha (PP)+ oxyfluorfen 0.250 kg/ha (POE)+ one hand wedding at 40 DAS, weedy check. Two months old seedlings of onion variety '*Baswant-780*', were transplanted in the month of August during 2010 and 2011 at a spacing of 45x10 cm on ridges and furrows type of layout. Pendimethalin was applied before one week of transplanting as pre-planting while oxyfluorfen was applied at 25 days after transplanting when weeds were at 3-4 leaf stage.

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RESULTS AND DISCUSSION

Effect on weeds

The prominent weed species in the experimental plot were: *Chenopodium album, Portulaca oleracea, Euphorbia* spp., *Cynodon dactylon, Parthenium hysterophorous, Cyperus rotundas* and *Amaranths viridis*. All treatments caused significant reduction in total weed density and dry weight of weeds as compared to unweeded control during both the years (Table 1). Significantly lower weed density was observed in weed free check (three hand weeding at 20, 40 and 60 DAS), however it was at par with treatment pendimethalin 1.0 kg/ha (PP) + oxyfluorfen 0.250 kg/ha (POE) + one hand wedding at 40 DAS. Also treatment oxyfluorfen 0.250 kg/ha (POE)+ one hand weeding at 40

Table 1. Effect of integrated weed management on various weed parameters in onion

Treatment	Weed density (no./m^2)			Dry weight of weeds (g/m^2)			Weed control efficiency (%)		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Weed free check	35.9	34.0	37.7	36.9	34.7	32.5	71.7	70.66	72.8
One hand wedding	72.3	72.9	71.6	78.3	76.1	73.9	50.5	53.12	48.0
Pendimethalin 1.0 kg/ha	80.2	80.0	80.5	78.6	76.4	74.2	45.9	52.13	39.8
Oxyfluorfen 0.250 kg/ha	80.0	81.7	78.3	74.4	72.3	70.1	52.3	51.77	52.8
Pendimethalin 1.0 kg/ha + one hand weeding	59.5	61.2	57.7	60.4	58.2	56.0	62.2	60.56	63.8
Oxyfluorfen 0.250 kg/ha + one hand weeding	53.1	54.7	51.4	56.6	54.4	52.2	60.7	61.89	59.4
Pendimethalin 1.0 kg/ha + oxyfluorfen 0.250 kg/ha	59.3	58.2	60.4	63.3	61.1	58.9	61.1	60.21	62.1
Pendimethalin 1.0 kg/ha + oxyfluorfen 0.250 kg/ha + one hand wedding	40.9	42.5	39.3	43.3	41.1	39.0	70.6	70.23	70.9
Weedy check	162.5	172.2	152.7	142.9	134.8	126.7	0	0	0
LSD (P= 0.05)	10.7	11.4	10.2	13.3	12.4	11.5	-	-	-

Table 2. Effect of integrated weed management practices on various growth attributes of onion

Treatment	Plant height (cm)		Neck thickness (cm)		Bulb weight (g)		Bulb diameter (cm)		Dry matter (g/plant)	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Weed free check	50.5	49.5	1.36	1.33	75.7	72.8	6.43	5.97	22.5	21.4
One hand wedding	30.8	30.1	1.22	1.19	43.6	41.7	3.22	3.44	12.9	11.6
Pendimethalin 1.0 kg/ha	27.7	27.2	1.17	1.18	38.8	38.5	3.78	3.32	11.4	10.7
Oxyfluorfen 0.250 kg/ha	26.1	25.3	1.15	1.17	39.8	37.9	3.51	3.19	11.7	10.7
Pendimethalin 1.0 kg/ha + one hand weeding	68.6	34.0	1.21	1.25	56.8	54.4	4.61	3.44	16.8	15.5
Oxyfluorfen 0.250 kg/ha + one hand weeding	34.1	33.6	1.26	1.22	61.2	59.2	4.67	3.91	18.3	17.5
Pendimethalin 1.0 kg/ha + oxyfluorfen 0.250 kg/ha	28.6	28.2	1.24	1.29	45.6	43.7	4.19	3.58	13.5	12.6
Pendimethalin 1.0 kg/ha + oxyfluorfen 0.250 kg/ha + one hand wedding	45.3	44.5	1.24	1.34	69.3	67.0	5.13	5.24	20.7	20.6
Weedy check	20.9	20.4	1.17	1.15	28.4	27.2	2.22	2.27	8.4	7.8
LSD (P= 0.05)	4.5	4.3	0.11	0.15	3.1	3.1	0.18	0.24	1.3	1.5

DAS, treatment pendimethalin 1.0 kg/ha (PP)+ one hand weeding at 40 DAS and treatment pendimethalin 1.0 kg/ha (PP)were on par with each other. Highest weed density and dry weight were recorded in weedy check. Highest weed control efficiency was observed in weed free check followed by pendimethalin 1.0 kg/ha (PP)+ oxyfluorfen 0.250 kg/ha (POE)+ one hand wedding at 20 DAS. Similar observations were also made by Kolhe (2001) and Warade *et al.* (2006).

Table 3. Effect of integrated weed management practices on yield and economics of onion

Treatment	Bulb yield (t/ha)			Gross monetary return (₹/ha)			B : C ratio		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Weed free check	26.93	25.24	26.09	1,88,510	1,76,680	1,82,595	2.53	2.37	2.45
One hand wedding	19.52	18.59	19.06	1,36,640	1,30,130	1,33,385	2.29	2.18	2.24
Pendimethalin 1.0 kg/ha	15.77	14.56	15.17	1,10,390	1,01,920	1,06,155	2.04	1.88	1.96
Oxyfluorfen 0.250 kg/ha	16.44	15.53	15.99	1,15,080	1,08,710	1,11,895	2.13	2.01	2.07
Pendimethalin 1.0 kg/ha + one hand weeding	21.14	20.39	20.77	1,47,980	1,42,730	1,45,355	2.40	2.32	2.36
Oxyfluorfen 0.250 kg/ha + one hand weeding	21.24	20.80	21.02	1,48,680	1,45,600	1,47,140	2.49	2.44	2.47
Pendimethalin 1.0 kg/ha + oxyfluorfen 0.250 kg/ha	19.63	18.45	19.04	1,37,410	1,29,150	1,33,280	2.45	2.30	2.38
Pendimethalin 1.0 kg/ha + oxyfluorfen 0.250 kg/ha + one hand wedding	24.12	23.30	23.71	1,68,840	1,63,100	1,65,970	2.81	2.71	2.76
Weedy check	9.48	8.74	9.11	66,360	61,180	63,770	1.27	1.17	1.22
LSD (P= 0.05)	2.18	2.25	2.22	2,559	1,935	2,247	-	-	-

Effect on crop growth

All the weed management treatments were significantly superior over control in respect of all growth attributes during both the years (Table 2). Significantly taller plants were observed in weed free check followed by pendimethalin 1.0 kg/ha (PP)+ oxyfluorfen 0.250 kg/ha (POE)+ one hand wedding at 20 DAS whereas lowest plant height was observed in treatment Weedy check.

The pooled data of the two experimental years revealed significantly higher neck thickness in weed free check over the control, however, treatments *viz.*, weed free check, pendimethalin 1.0 kg/ ha (PP)+ oxyfluorfen 0.250 kg/ha (POE)+ one hand wedding at 40 DAS, oxyfluorfen 0.250 kg/ha (POE)+ one hand weeding at 40 DAS, pendimethalin 1.0 kg/ha (PP)+ one hand weeding at 40 DAS and pendimethalin 1.0 kg/ha (PP)+ oxyfluorfen 0.250 kg/ha (POE) were at par with each other. Significantly higher bulb weight and bulb diameter were observed in weed free check (three hand weedings at 20, 40 and 60 DAS) over rest of the treatments, whereas weedy check recorded lowest and pendimethalin 1.0 kg/ha (PP)+ oxyfluorfen 0.250 kg/ha (POE)+ one hand wedding at 40 DAS were at the second place for these growth attributes.

In respect of dry matter per plant, weed free check recorded significantly higher weight over rest of the treatments, it was on par with pendimethalin 1.0 kg/ha (PP)+ oxyfluorfen 0.250 kg/ha (POE)+ one hand wedding at 20 DAS. Khalid Mahmood *et.al*. (2006) and Chandrika *et al.* (2009) also reported similar results from their studies.

Effect on yield

Significantly higher bulb yield per hectare and net monetary return per hectare were observed in weed free check over rest of the treatments (Table 3) followed by pendimethalin 1.0 kg/ha (PP)+ oxyfluorfen 0.250 kg/ha (POE)+ one hand wedding at 40 DAS whereas treatment weedy check produced lowest bulb yield per hectare. The treatments oxyfluorfen 0.250 kg/ha (POE)+ one hand weeding at 40 DAS, pendimethalin 1.0 kg/ha (PP)+ one hand weeding at 40 DAS, pendimethalin 1.0 kg/ha (PP)+ oxyfluorfen 0.250 kg/ha (POE) and one hand wedding at 20 DAS were on par with each other. These result in respect of yield attributes were in close conformity with the earlier findings of Sukhadia *et.al*. (2002) and Chopra and Chopra (2007).

Economics

The benefit: cost ratio was maximum for pendimethalin 1.0 kg/ha (PP)+ oxyfluorfen 0.250 kg/ha (POE)+ one hand wedding at 40 DAS and this index was varied in the range of 1.22 to 2.76, when weeds in onion were controlled either by herbicides or by hand weeding (Table 3). Though weed free check (three hand weeding at 20, 40 and 60 DAS) fetched the higher gross monetary return (₹ 182595/-) over all the other treatments, it had benefit: cost ratio (2.45) lesser than treatment pendimethalin 1.0 kg/ha (PP)+ oxyfluorfen 0.250 kg/ha (POE)+ one hand wedding at 40 DAS (2.76). It showed that treatment pendimethalin 1.0 kg/ha (PP)+ oxyfluorfen 0.250 kg/ha (POE)+ one hand wedding at 40 DAS was practically convenient and economically feasible for control of weeds in onion. Similar results were reported by Nandal and Singh (2002) and Patel *et al*. (2011)

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Bioefficacy testing of fenoxaprop-p-ethyl against weeds in direct-seeded rice

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ABSTRACT

The trial was conducted for two years during November–February 2006 and during December–April 2007. The treatments included fenoxaprop-p-ethyl at 47.44, 51.75, 56.06, 60.38 g/ha, cyhalofop-butyl 62.5 g/ha, *Echinochloa* spp. were the major weed comprising about 75% of the weed population. *Echinochloa crusgalli* and *Echinochloa stagnina* were present almost in equal proportions. Fenoxaprop-p-ethyl at all the tested doses was effective in controlling *Echinochloa* spp. Fenoxaprop sprayed 60.38 g/ha recorded yields on par with hand weeding and standard check cyhalofop. This dose can be recommended in situations where *Echinochloa* spp. is a major problem.

Key words: Direct seeded rice, Fenoxaprop-p-ethyl, Weed control

The success of rice cultivation depends on effectiveness of weed control measures In direct seeded rice, even total crop loss can occur due to weed competition. Pillai and Rao (1974) estimated the extent of yield reduction due to weeds to be over 50% in direct seeded upland rice, 30-35% in direct seeded rice under puddle condition and around 15-20% in transplanted rice. One estimate at IRRI showed that the weed growth in unweeded plots reduced yield by 34% in transplanted rice, 45% in direct seeded rain fed lowland rice and 67% in upland rice (De Datta 1981). Sankaran and De Datta (1985) reported yield reduction due to weed competition to the tune of 32 to 86% in upland rice. *Echinochloa* is a major crop associated weed of rice and cyhalofop butyl is the only herbicide recommended for the post-emergence control of this weed. Herbicide fenoxaprop-p-ethyl was also reported to control weeds in DSR when applied before the booting stage (Snipes and Street 1987). Fenoxaprop at 0.17 kg/ha applied as post-emergence after pre-emergence application of thiobencarb or pendimethalin controlled barnyardgrass in rice (Smith 1988, Khodayari *et al*. 1989). However Smith (1988) observed that fenoxaprop alone or in tank mixtures with other herbicides applied early as post-emergence either injured rice or failed to control weeds. Under these circumstances, a study was conducted to test the bioefficacy of a new post emergence herbicide fenoxaprop-p-ethyl to control *Echinochloa* spp. in direct seeded rice.

MATERIALS AND METHODS

The trial was conducted for two years during November–February 2006 and during December–April 2007. The experiment was laid out in RBD with six treatments and four replications. The plot size was 50 m^2 and the trial was conducted at the farm of Agricultural Research Station, Mannuthy of Kerala Agricultural University, located at 10 degrees 31' N latitude, 76 degrees 13' E longitude and at an altitude of 40.3m above mean sea level. The variety '*Jyothi*' (a short duration variety with 110-120 days duration) was shown. The soil of the experimental site was sandy loam with acidic pH of 5.6, organic carbon content of 0.66%, available N 276 kg/ha, available P 19.3 kg/ha and available K 89.6 kg/ha. The field was puddled and leveled and pre germinated seeds were sown.

The treatments included fenoxaprop-p-ethyl at 47.44, 51.75, 56.06, 60.38 g/ha (as Rice Star 6.9% EC supplied by M/S Bayer Crop Science Ltd., Mumbai), cyhalofop-butyl 62.5 g/ha (as Clincher 10% EC supplied by M/S Dow Agro Sciences, Mumbai). The herbicides were sprayed at 25-30 DAS with 500 litres/ha water using a knapsack sprayer fitted with a flood jet nozzle. Hand weeding was done at 20 and 40 days after sowing. Count of *Echinochloa* spp. was done before the treatment and 30 days after herbicide application and at flowering stage. Weed dry matter production was taken at 30 days after spraying and at harvest stage of the crop.

RESULTS AND DISCUSSION

Important weeds in the field were: *Echinochloa crusgalli* and *Echinochloa stagnina* among grasses, *Cyperus iria* and *Fimbristylis miliacea* among sedges and *Ludwigia parviflora, Monochoria vaginalis* and *Lindernia* sp. among broad leaved weeds. However *Echinochloa* spp. were the major weed comprising about 75% of the weed

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Table 1. Effect of fenoxaprop on *Echinochloa* spp. population and weed dry matter production during 2006

Treatment (g/ha)	*Echinochloa* spp. count (no./m²)			Dry weight (g/m²)	
	Pre-treatment	30 DAS	Harvest	30 DAS	Harvest
Fenoxaprop 47.44	6.87*(46.25)[ab]	2.23*(4.00)[b]	1.54*(1.50)[b]	1.70* (1.92)[b]	2.91*(8.75)[b]
Fenoxaprop 51.75	6.78(45.00)[b]	1.61(2.00)[bc]	1.41(1.00)[bc]	1.30 (0.95)[bc]	2.39 (4.75)[bc]
Fenoxaprop 56.06	6.87(46.25)[ab]	1.30(1.00)[c]	1.21(0.50)[bc]	1.12 (0.30)[c]	1.50 (1.52)[c]
Fenoxaprop 60.38	6.76(44.75)[b]	1.00(0.00)[c]	1.10 (0.25)[c]	1.00 (0.00)[c]	1.25 (0.75)[c]
Cyhalofop 62.5	6.89(46.50)[ab]	1.61(2.00)[bc]	1.10 (0.25)[c]	1.35 (0.97)[bc]	1.36 (1.00)[c]
Hand weeded	6.85(46.00)[ab]	1.00(0.00)[c]	1.21 (0.50)[bc]	1.00 (0.00)[c]	1.20 (0.50)[c]
Unweeded control	6.97(47.75)[a]	7.88(62.00)[a]	7.67(58.00)[a]	5.54(30.02)[a]	12.30(153.00)[a]
LSD (P=0.05)	0.14	0.82	0.36	0.47	1.33

Figures given in the parentheses are original values; *$\sqrt{x+1}$ transformed values

In a column, the figures followed by same alphabet do not differ significantly in Duncan's Multiple Range Test.

Table 2. Effect of fenoxaprop on *Echinochloa* spp. population and weed dry matter production during 2007

Treatment (g/ha)	*Echinochloa* count (no./m²)			Dry weight (g/m²)	
	Pre-treatment	30 DAS	Harvest	30 DAS	Harvest
Fenoxaprop 47.44	11.10(122.00)[a]	1.20*(0.50)[b]	1.57*(1.50)[b]	1.10(0.25)[b]	2.20(4.50)[c]
Fenoxaprop 47.44	11.20(124.20)[a]	1.00(0.00)[b]	1.49(1.25)[b]	1.00(0.00)[b]	1.00(0.00)[c]
Fenoxaprop 56.06	11.10(123.50)[a]	1.00(0.00)[b]	1.49(1.25)[b]	1.00(0.00)[b]	1.00(0.00)[c]
Fenoxaprop 60.38	11.10(123.00)[a]	1.00(0.00)[b]	1.31(0.75)[b]	1.00(0.00)[b]	1.00(0.00)[c]
Cyhalofop 62.5	12.10(148.50)[a]	1.20(0.50)[b]	1.31(0.75)[b]	1.10(0.25)[b]	2.30(4.00)[c]
Hand weeded	11.20(124.20)[a]	1.20(0.50)[b]	1.65(1.75)[b]	1.00(0.00)[b]	4.19(17.00)[b]
Unweeded control	11.20(125.50)[a]	13.00(169.50)[a]	10.50(109.5)[a]	4.40(18.25)[a]	18.50(344.00)[a]
LSD (P=0.05)	28.3	0.77	0.41	0.2	1.3

Figures given in the parentheses are original values; *$\sqrt{x+1}$ transformed values

In a column, the figures followed by same alphabet do not differ significantly in Duncan's Multiple Range Test.

Table 3. Effect of fenoxaprop on grain and straw yield of rice (kg/ha)

Treatment (g/ha)	2007		2008	
	Grain	Straw	Grain	Straw
Fenoxaprop 47.44	3932[a]	3944[ab]	3824[c]	4388[d]
Fenoxaprop 51.75	3800[a]	3900[ab]	3934[c]	4624[c]
Fenoxaprop 56.06	3800[a]	3893[ab]	3983[c]	4663[c]
Fenoxaprop 60.38	4050[a]	4445[a]	4382[b]	5175[b]
Cyhalofop 62.5	3800[a]	4735[a]	4501[b]	5096[b]
Hand weeded	3900[a]	3987[ab]	4860[a]	5529[a]
Unweeded control	1950[b]	3437[b]	2071[d]	3680[e]
LSD (P=0.05)	336	790	591	261

In a column, the figures followed by the same alphabet do not differ significantly in Duncan's Multiple Range Test.

population. *Echinochloa crusgalli* and *Echinochloa stagnina* were present almost in equal proportions.

All the doses of fenoxaprop resulted significant reduction in the count of *Echinochloa* spp. at 30 days after spraying in both the years of study (Table 1 and 2). The weed dry matter production also showed a similar trend. Snipes and Street (1987) also obtained good control of *Echinochloa* spp. by fenoxaprop. Although there was progressive reduction in the *Echinochloa* population with increase in the doses of fenoxaprop, there was no significant difference among higher three doses (51.75 g/ha, 56.06 g/ha, 60.38 g/ha). These doses were also on par with cyhalofop-butyl, the presently recommended post-emergence herbicide against *Echinochloa*, as well as with hand weeding. As expected, cyhalofop as well as fenoxaprop, did not give control of sedges and broad-leaved weeds.

All the herbicide treatments resulted in significant increase in the grain yield compared to unweeded control in both years (Table 3). In the first year of study, there was no significant difference between different doses of fenoxaprop, which were also on par with cyhalofop and hand weeding. The highest grain yield was in the plots sprayed with fenoxaprop at 60.38 g/ha (4050 kg/ha) followed by hand weeded control (3900 kg/ha) and the standard check cyhalofop (3800 kg/ha). Fenoxaprop at 60.38 g/ha and cyhalofop 62.5g/ha recorded significantly higher straw yields also. There was no significant difference between straw yields in any of the herbicide treatments. The lowest straw yield was recorded in unweeded control (3437 kg/ha), which was significantly lower than fenoxaprop 60.38 g/ha and cyhalofop 62.5 g/ha.

In the second year of study, hand weeding resulted in significantly higher grain yield (4860 kg/ha) than the herbicide applied plots. The highest grain yield was recorded by hand weeding since broad-leaved weeds and sedges had also been hand weeded along with grass weeds. This was followed by cyhalofop (4501 kg/ha) and fenoxaprop 60.38 g/ha (4382 kg/ha), which were on par with hand weeded plot. Maximum straw yield of 5529 kg/ha was also produced by hand weeding where as lowest was in unweeded control (3680 kg/ha). As in the case of grain, cyhalofop 62.5 g and fenoxaprop 60.38g were on par.

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Evaluation of post-emergence herbicides in rainy season groundnut

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ABSTRACT

An experiment was conducted at Oilseeds Research Station, Jalgaon during 2007 to 2009 in order to control groundnut associated weed growing in *Kharif* season. An experiment was done with seven treatments of pre and post-emergence herbicides comprising weedy cheek and weed free check replicated thrice in randomized block design (RBD) on medium clay loam soils with pH 8.1. The various weeds observed in groundnut field during *Kharif* season were, *Amaranthns viridus, Parthenium hysterophorus, Acalypha indica, Cyperus rotundus , Cynodon dactylon, Phyllanthus niruri, Commelina* spp., *Eragrostic* sp., *Celosia argenia* and *Euphorbia* sp. Among the grasses, *Cynadon dactylon* was predominant and among the sedges *Cyperus rotundus* was predominant. Among the different herbicides, pre-emergence application of pendimethalin 1.0 kg/ha + post-emergence application of imazethapyr 75 gm/ha at 20 DAS recorded maximum weed control efficiency (74%), minimum weed population (42.67/m^2) and weed day matter (185 g/m^2). The same treatment combination recorded significantly higher dry pod yield (1997 kg/ha), gross returns (46445/ha) net returns (28705/ha) and B: C ratio 2.44.

Key words: Groundnut, Herbicide, Post-emergence, Pre-emergence, Weed control efficiency

Groundnut (*Arachis hypogaea* L.) is one of the most important oilseeds crops in India. Groundnut contributes more than 50% edible oil production of the country. The demand for edible oil is rising day by day. Area as well as productivity of this crop declined drastically. Therefore, concentrated efforts are being made to increase and to stabilise the oilseeds production. Groundnut is the most popular oilseeds crop of *Kharif* season. The National average productivity (1040 kg/ha) of groundnut in India (Anonymous 2009) was less than the world average (1600 kg/ha). Among the various factors responsible for low yields of groundnut, severe infestation of weeds during the early crop growth period is one of the constraints. Due to slow initial growth, it caught in rains which favours severe weed infestation. If the field left uncontrolled these may reduce the groundnut yields up to 78%. (Gnanamurthy and Balashbramanian 1998). Present investigation aims to control early weeds of the groundnut crop during rainy season with the help of combinations of pre and post applied herbicides.

MATERIALS AND METHODS

An experiment was conducted at research farm of Oilseeds Research Station, Mahatma Phule Krishi Vidyapeeth, Jalgaon during *Kharif* season of 2007 to 2009 in order to find suitable pre and post-emergence herbicide for the control of weeds during early growth stage of groundnut crop. The experimental field was medium to deep clay loam soil with pH 8. Fertility status of experiment field was low in nitrogen (198 kg/ha), medium in phosphorus (20 kg/ha) and high in potash (685 kg/ha). The crop was raised with 25 kg/ha N and 50 kg/ha P_2O_5 with cultivar *'Phule Unap (JL-286)'*. A set of seven treatment combinations with pre-emergence pendimethalin and post-emergence herbicide imazethapyr and quizalofop-ethyl comprising weedy check and weed free check was made and replicated thrice in randomized block design (RBD).

The pre-emergence herbicides was sprayed immediately after sowing on wet soil and the post-emergence herbicides was applied 20 days after sowing with the help of knapsack sprayer with discharge rate of 500 l/ha. Weed population and weed dry matter, taken at 30 DAS and at harvest was recorded by using the quadrate measuring 1 m^2 per plot. The weed control efficiency (WCE) and B: C ratio was worked out.

RESULTS AND DISCUSSION

Weed flora

Weeds observed in the experimental field of groundnut during *Karif* season were: *Phyllanthus niruri, Euphorbia* spp., *Amaranthus* spp., *Celosea argentia, Parthenium hysterophorus, Bidens pilosa, Commelina* spp., *Cyperus rotundus, Cynodon dactylon etc.* Among the grasses *Cynodan*

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dactylon was predominant and *Cyperus rotundus* predominant among sedges. Suryawanshi *et al.* (2001) observed the similar weed flora in *Kharif* groundnut on medium clay loam soils of Khandesh region of Maharashtra.

Weed density and weed dry matter production

The treatment pre-emergence application of pendimethalin 1.0 kg/ha + post-emergence application of imazethapyr 75 gm/ha at 20 DAS recorded significantly least number of weed (42.67) and weed dry matter (167 gm/m^2) than any other treatment except weed free check (21.3 and 88/m^2, respectively) (Table 1). This might be due to control of weeds during early growth stage by pre-emergence application of pendimethalin and post emergence application of imazethapyr at 20 DAS. The treatment combination of pre and post applied herbicide after sowing and 20 DAS was able to control the further infestation of weeds in groundnut crop. Further the crop covers the soil surface and smothers the growth of weeds results into least number of weeds at harvest.

Table 1. Pooled mean weed density, weed dry matter and weed control efficiency as influenced by different weed management practices

Treatment	Weed density at harvest (m^2)	Weed dry matter (g/m^2)	Weed control efficiency (%)	Weed index
T1: Unweeded control	95.5	580.8	0	65.0
T2: Weed free check	18.9	78.0	100	0.0
T3: Pendimethalin 1.0 kg/ha PE + 1 HW	45.2	176.2	70	14.3
T4: Qquizalofop-ethyl 750ml/ha PE at 20 DAS	70.5	324.6	44	48.3
T5: Imazethapyr 750 ml /ha) PE at 20 DAS	51.5	177.9	66	22.8
T6: Pendimethalin 1.0 kg/ha PRE + T4	51.5	198.1	67	42.0
T7: Pendimethalin 1.0 kg/ha PRE +T5	42.7	185.1	74	14.8
LSD (P=0.05)	27.1	112.9	9.80	-

Table 2. Pooled mean dry pod, haulm yield and economics of groundnut as influenced by different treatments

Treatment	Dry pod yield (kg/ha)	Haulm yield (kg/ha)	Gross returns (₹)	Cost of production (₹)	Net returns (₹)	B:C ratio
T1: Unweeded control	821	4,378	21,971	17,944	4,027	1.22
T2: Weed free check	2,344	5,842	55,782	24,544	31,238	2.27
T3: Pendimethalin 1.0 kg/ha PE + 1 HW	2,008	5,480	47,549	22,629	24,920	2.10
T4: Quizalofop-ethyl 750ml/ha PE at 20 DAS	1,212	5,023	31,087	19,197	11,890	1.62
T5: Imazethapyr 750 ml/ha) PE at 20 DAS	1,810	5,436	44,193	19,456	24,737	2.27
T6: Pendimethalin 1.0 kg/ha PRE + T4	1,360	5,249	34,647	20,894	13,753	1.66
T7: Pendimethalin 1.0 kg/ha PRE +T5	1,997	5,448	49,779	21,074	28,705	2.36
LSD (P=0.05)	347	187	8,257	-	8,159	0.49

Weed control efficiency and weed index

The treatment T_7 pre-emergence application of pendimethalin 1.0 kg/ha + post-emergence application of imazethapyr 75 gm/ha at 20 DAS was recorded significantly highest weed control efficiency (74%) than any other weed control treatment (Table 1) except weed free check (100%). The lowest weed index was noticed in treatment of pendimethalin 1.0 kg/ha PRE + 1 HW (14.33) followed by pre-emergence application of pendimethalin 1.0 kg/ha + post-emergence application of imazethapyr 50 gm/ha at 20 DAS (14.80). The yield reduction up to 65% was recorded if field kept un-weeded. Ramkrishna *et al.* (1990) observed the similar trend in efficacy of herbicide in groundnut crop. This might be due to the continuous competition of groundnut crop with the obnoxious weed species for nutrient and moisture.

Yield and economics

Among the different herbicides, application of pendimethalin 1.0 kg/ha + post-emergence application of imazethapyr 75 gm/ha at 20 DAS recorded significantly higher dry pod yield (1997 kg/ha), gross returns (₹ 46445/ha), net returns (₹ 28705/ha and B:C ratio 2.44) than other treatment except weed free check (Table 2). The yield of groundnut was mainly reduced due to the presence of weeds throughout the growing period. Ramkrishna *et al.* (1990) observed the similar trend in efficacy of herbicide in groundnut crop. This might be due to the continuous competition of groundnut crop with the obnoxious weed species for nutrient and moisture.

Efficient and profitable management of weeds through pre-emergence application of pendimethalin 1.00/ha + post-emergence application of imazethapyr 50 gm/ha at 20 DAS was most profitable way of controlling weeds in groundnut during rainy season.

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Effect of seed rate and weed control methods on productivity and profitability of wetland rice under medium land conditions

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ABSTRACT

A field experiment was conducted at Ranchi, Jharkhand during rainy seasons of 2010 and 2011 to find out the effect of seed rate and weed control methods on wet seeded rice under medium land condition. Increasing seed rate from 60 to 120 kg/ha did not influence weed density and weed dry matter at 20 and 40 DAS. Application of pyrazosulfuron 0.02 kg/ha early post-emergence reduced density of all categories of weeds. The mean reduction was 61.9 and 35.3% and 66.7 and 41.9% at 20 and 40 DAS compared to butachlor and 2 hand weeding respectively. Pyrazosulfuron being similar to Almix (chlorimuron + metsulfuron) 20 g/ha recorded 70.3 and 87.0% reduced weed dry matter compared to weedy check. Application of 80 kg seed/ha being similar to 100, and 120 kg seed/ha recorded 63.0% higher grain (2.70 t/ha) and 70.9% higher straw (3.81 t/ha) yield compared to 60 kg seed/ha.

Key words: Chemical control, Productivity, Rice, Seed rate

In Jharkhand, raising seedlings and transplanting of rice are on the mercy of monsoon, which is erratic in onset and distribution, intensity and cessation. Invariably seedlings overgrow in the nursery waiting for rains adequate to perform puddling operation. As a result overgrown seedlings are planted and the crop starts flowering soon thereafter, leading to reduced yield. Wet seeding can be practiced as an alternative to transplanting as it holds promise for saving labour, time and energy and ensures efficient water use and increased benefit : cost ratio. Seed rate plays an important role which is kept usually high to the minimize weed menace. However, higher seed rate may produce frail and taller rice plant with lower number of panicles per unit area owing to intra-plant competition, while lower seed rate may result in greater weed occurrence. Present investigation was taken up to study the effect of seed rate and weed control methods on weed dynamics and productivity and profitability of wet-seeded rice.

MATERIALS AND METHODS

An experiment was conducted during 2010 and 2011 at research farm of Birsa Agricultural University, Ranchi. The field was typical medium land, with soil low in organic C (0.41%), available N (185 kg/ha) and K (142 kg/ha) and medium in available P (15 kg/ha).Treatments comprised of four seed rates, *viz.*, 60, 80, 100, and 120 kg/ha and five weed management practices, *viz.*, butachlor1.5 kg/ha pre-emergence, pyrazosulfuron 0.02 kg/ha post-emergence, Almix (chlorimuron + metsulfuron) 4 g/ha post-emergence, two hand weedings at 20 and 40 days after sowing, and weedy check. The experiment was conducted in a randomized block design replicated thrice.

Before sowing, the field was ploughed with the help of mould board plough followed by puddling by cultivator in standing water of 10 cm depth followed by planking. Seed of rice variety '*Lalat*' as per treatment were weighed and soaked overnight and kept wrapped in wet cloth for sprouting for 24 h. The crop was sown on 18 July 2010 and 23 July 2011 and harvested on 14 November 2011 and 19 November 2011. Application of fertilizers 100 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha were applied in the form of urea, diammonium phosphate and muriate of potash, respectively. Half dose of N and full amount of P and K were applied as basal. Rest half of nitrogen was applied in two equal splits at maximum tillering and panicle primordial initiation stage.

RESULTS AND DISCUSSION

Weed growth

The experimental field was infested with all three categories of weeds under six families. The total number of species were 12, out of which, *Echinochloa colona*, *Eleusine indica*, *Digitaria sanguinalis* and *Paspalum distichum* among grasses, *Ludwigia parviflora*, *Sphellanthus acmella*, *Eclipta alba* and *Commelina benghalensis* among BLW and *Cyperus iria, Fimbristylis*

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Table 1. Effect of Seed rate and weed control methods on weed density in rice crop (mean of 2010 and 2011)

Treatment	Weed count (no./m^2)						Weed dry weight (g/m^2)	
	20 DAS			40 DAS				
	Narrow	BLW	Sedges	Narrow	BLW	Sedges	20 DAS	40 DAS
Seed rate (kg/ha)								
60	17	18	3	12	30	12	7.8	11.2
	(305)	(388)	(15.7)	(158)	(967)	(179)	(67.5)	(166)
80	15	16	3.1	11	29	12	7.1	10.3
	(264)	(326)	(13.2)	(120)	(910)	(178)	(53.4)	(137)
100	15	16	2.4	10	29	12	6.8	10.5
	(226)	(311)	(7.68)	(118)	(889)	(175)	(48.3)	(136)
120	13	14	2.2	11	29	12	5.9	10.5
	(174)	(235)	(6.14)	(150)	(867	(175)	(36.4)	(134)
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Weed control method								
Butachlor 0.5 kg/ha	14	18	3.6	12	29	14	6.41	13.8
	(208)	(366)	(13)	(150)	(844)	(213)	(41.7)	(201)
Pyrazosulfuron 0.20 kg/ha	12	7.7	0.8	11	23	6.6	5.2	6.5
	(152)	(71.1)	(0.3)	(141)	(580)	(59)	(27.4)	(46.2)
Almix 4 g/ha	14	14	1.9	14	26	9.7	5.9	8.8
	(201)	(262)	(4.6)	(188)	(747)	(123)	(36.4)	(85.1)
Weed-free	17	18	3.5	4.9	34	11	7.51	4.9
	(309)	(346)	(16)	(24)	(1201)	(117)	(59)	(24.7)
Weedy check	18	23	3.8	13	34	19	9.53	18.9
	(341)	(530)	(19)	(179)	(1170)	(371)	(92.5)	(358)
LSD (P=0.05)	NS	10.2	2.5	5.4	9.6	7.6	2.9	7.6

Data subjected to square root transformation. Original values are in parentheses

Table 2. Yield attributes and yield of rice as influenced by seed rate and weed control methods (mean of 2010 and 2011)

Treatment	Tillers/m^2		Grains/panicle		Yield (t/ha)		Cost of cultivation ($x10^3$ ₹/ha)	Net returns ($x10^3$ ₹/ha)	B:C ratio
	Total	Effective	Filled	Unfilled	Grain	Straw			
Seed rate (kg/ha)									
60	317	262	69	40	1.65	2.22	15.71	7.25	1.11
80	396	337	93	40	2.70	3.80	16.19	21.69	1.97
100	425	306	62	40	2.58	3.17	16.67	18.39	1.72
120	380	283	54	38	2.17	2.80	17.15	12.64	1.33
LSD (P=0.05)	NS	73	NS	NS	1.02	1.45			
Weed control method									
Butachlor 0.5 kg/ha	365	262	61	40	1.99	2.62	15.65	11.84	1.39
Pyrazosulfuron 0.20 kg/ha	480	337	66	44	2.86	3.80	15.46	24.14	2.21
Almix 4 g/ha	420	306	63	42	2.32	3.20	15.20	17.23	1.79
Weed-free	365	283	61	36	2.82	3.56	20.90	17.65	1.32
Weedy check	267	190	60	36	1.37	1.81	14.90	4.09	0.94
LSD (P=0.05)	131	90	NS	NS	1.02	1.58			

milliaceae, Cyperus difformis, Kyllinga brevifolia among sedges were present as major weeds in rice fields. Increasing seed rate from 60 to 120 kg/ha did not influence weed density and weed dry matter at 20 and 40 DAS. Mahajan *et al.* (2006) have also found that enhanced seed rate did not influence weed density as well as weed dry matter. Application of herbicides *i.e*. butachlor, pyrazosulfuron, almix (chlorimuron + metsulfuron) as well as 2 hand weeding reduced total density of all categories of weeds compared to weedy check. Among herbicides, application of pyrazosulfuron was similar to almix in controlling broadleaved weeds and sedges at 20 and 40 DAS. The mean reduction in total weed density due to application of pyrazosulfuron was 61.9 and 35.3% and 66.7 and 41.8% at 20 and 40 DAS compared to butachlor and 2 hand weedings, respectively. Application of herbicides significantly reduced weed dry matter at 20 and 40 DAS. Application of pyrazosulfuron was on par with hand weeding at 40 DAS. Pyrazosulfuron being similar to Almix recorded 70.3 and 87.0% reduced weed dry matter at 20 and 40 DAS, respectively compared to weedy check. Similar findings were reported by Chopra *et al.* (2003).

Yield and economics

Rice crop sown with 80 kg seed/ha being similar to 100, and 120 kg seed/ha recorded 63.0% higher grain (2.70 t/ha) and 70.9% higher straw (3.81 t/ha) yield compared to 60 kg seed/ha, thereby recorded maximum net returns (₹ 21,692/ha) and benefit : cost ratio (1.97). Among weed control methods, application of pyrazosulfuron 0.20 kg/ha being similar to butachlor 0.5 kg/ha, Almix 4g/ha and hand weeding recorded 107.9% higher grain (2.86 teed/ha) and 110.1% higher straw yield compared to weedy check, thereby registering maximum net returns (₹ 24,147/ha) and B:C ratio (2.21).

It can be concluded that 80 kg seed/ha recorded higher productivity and profitability of rice crop grown as direct-seeded under wetland situation. Application of pyrazosulfuron 0.20 kg/ha was most effective in controlling weeds and recording maximum productivity and profitability.

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Techniques to reduce pollution by enhancing cuticle loading and entry of herbicide

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ABSTRACT

Technique enhancing herbicide entry into the plants leads to reduction in dosage and therefore pollution. Higher density of fine droplets along with surfactant increased the herbicide entry points, than coarse droplets for same total spray volume. But fine droplets evaporate faster resulting in herbicide getting deposited as dried crystals on leaf surface. To overcome this problem, several adjuvants were tried to increase the time required for evaporation. Jaggery (2%) increased the evaporation period (27-162%) on different weed species. Dried out deposition of radioactive glyphosate from fine drops and along with TritonX 200 was more but showed enhanced glyphosate entry into the plant system. Whereas, aqueous extract (2%) of soap nut fruit (*Sapindus emarginatus*) which acts as bio-surfactant and antioxidant increases the time taken for drying and therefore enhances the translocation of glyphosate to bulb of *O. latifolia,* which was on par with TritonX 100 surfactant (petroleum product). This approach seems to be more beneficial than increasing the dosage of herbicide per droplet.

Key words: Adjuvants, Dried-out deposit, Foliar herbicide

Deposition of droplet on the foliage is the prerequisite for effective uptake of foliar applied herbicide. More density of fine droplets covering the entire leaf surface area and having the same volume of a single coarse droplet, leads to increased entry points and enhanced cuticle loading of the foliar applied herbicide (Devendra *et al.* 2009). However, finer the droplet with surfactant shortens the evaporation period of the droplet, reduced herbicide entry time significantly due to spreading of the droplet (Ashok 2007). Further, Shweta (2009) showed that increasing the dosage of herbicide per drop (x and 2x of radioactive glyphosate, 2,4-D) increased the dried out deposit 67 to 91% and 68 to 77% of glyphosate and 2,4-D on foliage of water hyacinth (*Eichhornia crassipes*). All the radioactive herbicide studies indicated 60-85% of foliar applied herbicide remains as dried out deposit on the epi-cuticular wax. Adjuvants were added by company along with formulations or by farmers as tank mix to aid as wetting, spreading, deposit building, emulsifying, deflocculating, wetting of the leaf cuticle, increase spray retention, protection of the herbicide in the spray solution, promote rainfastness, acts as a co-penetrant *etc.* (Hazen 2000, Penner 2000).

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Adjuvants *viz.*, TritonX 200 (acts as surfactant and humectants), PEG 400 (humectant), Arial (detergent), ethephon or glyphosate (senescence inducing agents), 8 hydroxy quinoline (anti-callose accumulating agent in phloem sieve element); Sure shot **(**rain fastness agent) along with Meera 71.

WS granular formulation of glyphosate, citric acid or ammonium sulphate (anti-chelating agent) prevent chelating of ionized glyphosate molecule with divalent cations Fe^{++}, Ca^{++}, Mg^{++} *etc.* present in the hard water were tried to enhance cuticle loading and translocation of foliar herbicides from fed leaf to the underground plant parts of *Cyperus rotundus* and *Oxalis latifolia*. TritonX 100 or 200 (TX 100 or TX 200) was the best surfactant for glyphosate with ethephon concentration 5000 ppm was not economical, Sure shot did not protect the herbicide droplet against rain wash off. Jalendra Kumar 2004 Further, he showed that *Cyperus rotundus* being easy to wet but difficult to control having predominantly underground plant parts whereas, *Oxalis latifolia*itis difficult to wet, but responds to surfactant. Thus these two weed species were used to test the effectiveness of the adjuvants.

Experiments with surfactant showed that varied ethylene oxide (EO) repeats, less EO for sethoxydim (lipid soluble) and more EO for glyphosate (water soluble) enhanced their potency by enhancing spread, co-penetration, cuticle loading and increased movement across cuticle

(Devendra *et al.* 2001). In-spite of negative relation between surface tension of spray solution and droplet spread (Devendra *et al.* 2000), low surface tension of 67.7 mN/m by Laffmul DA (vegetable oil concentrate) enhanced the efficacy of glyphosate, glufosinate, whereas high surface tension of 76.4 mN/m by ethoxylated castor oil enhanced the efficacy of imazapyr and oxyfluorfen may protect them from photo-oxidization by UV rays of sun and no effect on 2,4-D and imazethapyr as reflected by dry weight reduction bioassay of *C. rotundus* and *O. latifolia* (Devendra *et al.* 2004). Hence, single surfactant for all herbicide can not be recommended. Root absorbs silicon as silicic acid, gets converted it as silicon gel in leaf blade and deposits beneath thin cuticle (0.1mm) as cuticle-Si double layer as thick as 2.5mm (Ma and Yamaji 2006). Silicon surfactant known to enhance entry of herbicide and protect the droplet wash off by rain by forming glass like substance over droplet.

With this in background, experiments were conducted to assess 1) the effect of different anti-drift flood jet nozzles and TritonX 200 on droplet spread on different weed spp, 2) effect of adjuvants on droplet drying period on different weed species foliage and 3) effect of bio-surfactant *Sapinduse marginatus* extract and silicon (rain fastness) on ^{14}C-glyphosate dry deposit, entry and translocation in *Oxalis latifolia*.

MATERIALS AND METHODS

Effect of varied nozzle with or without surfactant on weed foliage droplet deposition

Leaf bits of 2.5 x 1.5 cm (length x width) from weed species *viz., Cyperus rotundus, Oxalis latifolia, Lagas camollis, Digitaria marginata,Dactyloctenium aegyptium, Parthenium hysterophorus* and *Chromolaena odorata* were adhered to glass slides with double sided sticker tape. Care was taken so that upper surface of leaf was exposed to spray. The slides were sprayed *in vitro* using varied orifice nozzles (Table 1) with or without TritonX 200, from a height of 0.5 m with 15 PSI pressure. Spray was replicated three times on different sets of all species leaf bits. Spectrum of droplets deposited on the foliage was viewed from top through binocular microscope. Diameter of droplet and frequency of deposition was recorded using ocular micrometer attached to one eye piece. Drop diameter was measured with fixed magnification (10x optical lens with 1.8 zooming) and expressed in millimeter (mm) (eq 1) by giving calibration conversion factor 0.057 obtained from stage micrometer.

Drop diameter (mm) = No. of division of ocular micrometer x 0.057 ——(1)

Mean of five spray were used to arrive at Number Median Diameter (NMD) using eq 2.

Median = Lower valve of group where median lies + (B/D) x C ——(2)

Where B = 50–A, A indicates cumulative percentage of preceding interval of group where median lies (which was identified by Median = (n+1)/2, n is the total number of observations or total of all frequency), C is the range of median interval and D is the cumulative percentage for the median interval. NMD values were statistically analyzed using factorial CRD.

Effect of adjuvants on weed species foliage droplet drying period

Under laboratory conditions on the foliage of different weeds (Table 2), single coarse drop 5 µl of glyphosate (1.5 kg /ha) with or without different adjuvants *viz.*, TritonX 200 (0.05%), 8-hydroxy-quinoline (1mM), citric acid (0.01%), ammonium sulphate jaggery or sucrose (2% each) were placed on upper surface and droplet drying period (min.) were recorded. Thrice repeated and factorial CRD was used for statistical analysis.

Effect of fine drop

TritonX 200, extract of *Sapinduse marginatus* and soluble silicic acid on ^{14}C-glyphosate dried out deposit, entry and translocation in weed species were studied. Thirty day old seedling were raised in ice-cream cups of size 10 cm diameter at brim and 7.5 cm depth filled with red loamy soil: sand: FYM in 3:1:1 proportion with required NPK , and were irrigated and used for this study.

Preparation of ^{14}C-glyphosate with or without adjuvants

^{14}C-glyphosate with specific activity of 0.01 mci/mole obtained from Sigma-Aldrich was mixed with 1 ml 2000 ppm unlabeled (cold) glyphosate (Roundup 41SL). From this stock, 10 µl of labeled glyphosate was taken and 1 µl of cold glyphosate with or without adjuvants (Table 3 and Fig.1) was added to obtain various treatments. Methane and aqueous extract of *Sapindus emarginatus* were prepared by boiling 20 g dried fruit rind in methanol or water in 100 ml for 20 min and aged for over night and filtered using Whatman filter paper and diluted (2%) in the cold glyphosate.

Technique of feeding

Single drop of 1 µl or 5 drops of 0.2 µl of ^{14}C-glyphosate with or without adjuvants were carefully placed on fully expanded young leaf of weeds, 4th or 5th from top. Placed droplet was marked with water proof maker pen. After 72 h of feeding, plant parts *viz.*, fed leaf, other leaves, stem and root/bulb/tubers were separated. After separating the fed spot from fed leaf, fed spot was washed off by dipping in water and the activity was assessed as dried out deposit. Remaining portion of fed leaf, other leaves, stem, root, bulb/tubers were macerated using passel and mortar in known amount of distilled water and a known aliquot was assessed for radio activity, which was measured using Liquid Scintillation Counter (Wallac Model 1414) and expressed as CPM/organ fresh wt. or CPM/g fresh wt. In different weed species, per cent activity of finer drop with or without TX200 over single coarse drop of glyphosate alone was calculated for dried out deposit and total of different plant parts (Fig.1). Factorial CRD was used for statistical analysis with three replicated data.

RESULTS AND DISCUSSION

Nozzle effect on droplet deposition

Diameter of the droplet deposited on different weed species foliage was significantly more compared to without surfactant (TX200) for both nozzles. Whereas, on *D. aegyptium* and *C.odorata,* droplet spread was not significant with TX200 when sprayed with 0.8 mm nozzle but significant with 2.4 mm nozzle (Table 1). Highest droplet diameter was recorded with wider orifice nozzle sprayed along with surfactant on all weed species foliage. Data suggest that, spraying with narrow orifice nozzle, even with surfactant, deposited droplet will not cause run off from the leaf surface and NMD was close to recommended drop diameter (100 mm NMD) for foliar applied translocative herbicide. Further, volume of solution for 64 finer drop droplets of 125 mm diameter is equal to single coarse drop of 500 mm diameter and finer droplets cover the entire leaf surface, thus more herbicide entry points was available (Manjunatha 2003).

Adjuvant effect on dried out deposit and ^{14}C-glyphosate uptake and translocation

Small droplet with surfactant, significantly enhanced dried out deposit and entry into the plant system of ^{14}C-glyphosate at the fed spot than without surfactant due to spread of the droplet on the foliage, except in *D. marginata* and *D. aegyptium* (Fig.1). Mean time for droplet evaporation over weed species with or without TX200 was 9–60 m and was 36% less in finer drop (2 µl) than coarse drop (5 µl). Further, with TX200, evaporation time was 6, 12.5, 12.8 and 18% less over without from fine drop on *O. latifolia*, *D. marginata*, *C. rotundus* and *L. mollis* foliage, respectively (Ashok 2007). Thus, with finer drop with the surfactant, droplet dries out fast and herbicide molecules may not be able to load into the cuticle fully.

To prolong the period of droplet drying on the foliage, various adjuvants were tried. Amongst adjuvants, jaggery (2%) delayed drying significantly compared to other adjuvants in all weed species except in *C. rotundus* (Table 2). Further, jaggery increased sucrose level in the spray solution which might increase phloem loading in the foliage and enhances translocation to other plant parts. Biomass reduction of *O. latifolia* and *C. rotundus* bioassays showed significant reduction with TX200 + jaggery than glyphosate alone (Ahok 2007).

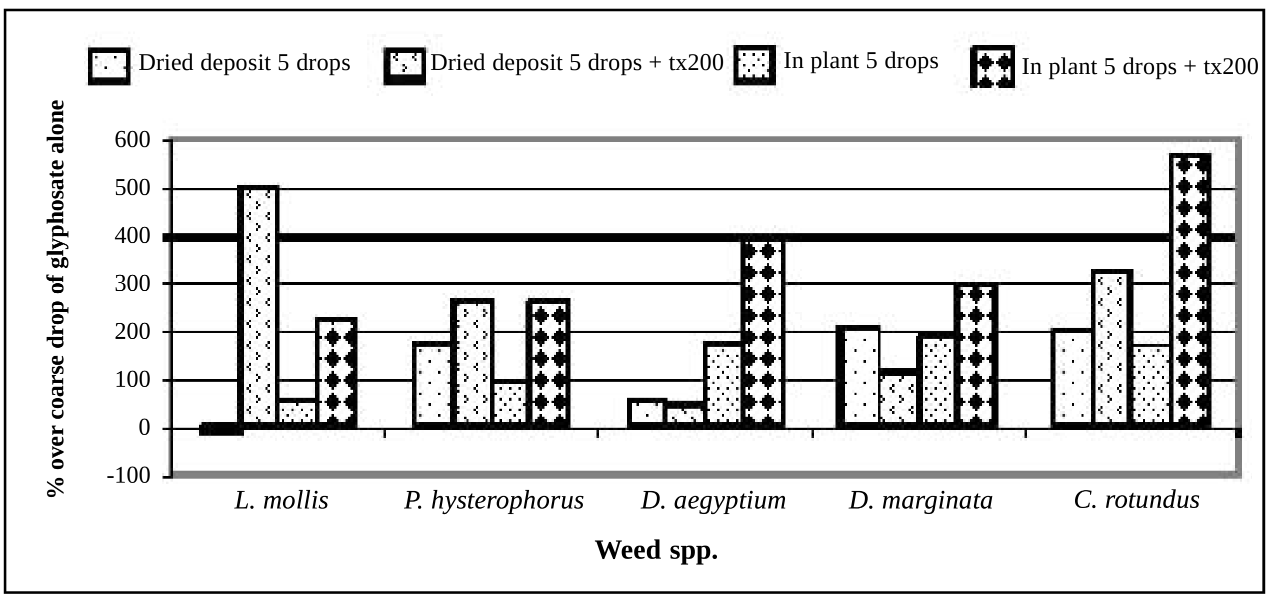

Fig. 1 Effect of finer drop deposition and surfactant on per cent dried out and in the plant system of glyphosate after 72 h feeding

Table 1. Effect of spray fixed with different nozzles, with or without TritonX 100, on Number Median Diameter (NMD) of droplet deposited on weed species foliage

Weed Species	Anti-drift flood jet nozzle having varied orifice size			
	0.8 mm		2.8 mm	
	Water	Water + TritonX 200	Water	Water + TritonX 200
C. rotundus	469^{l}	1025^{de}	720^{g-k}	1593^{a}
O. latifolia	627^{i-l}	844^{fg}	639^{gh}	1375^{b}
L. mollis	563^{kl}	750^{g-j}	1023^{d-f}	1225^{bc}
D. marginata	562^{kl}	781^{g-i}	781^{fh}	1094^{cd}
D. aegyptium	639^{h-k}	657^{h-k}	844^{fg}	1083^{cd}
P. hysterophorus	594^{j-l}	812^{gh}	614^{i-l}	1083^{cd}
C. odorata	594^{j-l}	666^{g-l}	1000^{d-f}	1083^{cd}
	LSD (P=0.05) 180			

In a column, the figures followed by same alphabet do not differ significantly.

Table 2. Effect of adjuvants on droplet (5 µl) drying period (minute) on different weed species

Adjuvants to glyphosate (1.5 kg/ha)	*O. latifolia*	*D. marginata*	*L. mollis*	*C. rotundus*
Glyphosate alone	51^{c}	50^{c}	17^{e-g}	22^{d-g}
TritonX 200 (0.05%)	48^{c}	50^{c}	17^{e-g}	28^{d}
8 Hydroxy-quinone (0.5%)	49^{c}	45^{c}	15^{g}	22^{d-g}
Ammium sulfate (2%)	45^{c}	49^{c}	24^{d-f}	26^{de}
Sucrose (2%)	94^{b}	92^{b}	16^{fg}	24^{d-g}
Jaggery (2%)	132^{a}	131^{a}	42^{c}	28^{d}
Citric acid (0.01%)	131^{a}	127^{a}	18^{e-g}	25^{de}
	LSD (P= 0.05) 8.75			

In a column, the figures followed by same alphabet do not differ significantly.

Table 3. Effect of soapnut (*Sapinduse marginatus*) extract (2%) and silicon (0.4%) on ^{14}C-glyphosate dry deposit on cuticle, entry and translocation in *Oxalis latifolia*

Treatment	DD	Fed spot	x10^2 CPM/organ weight			x 10^2 CPM/g organ weight		
			Fed leaf	Other leaves	Bulb	Fed leaf	Other leaves	Bulb
Glyphosate	115	25	25^{lm}	146^{f-h}	517^{c}	123^{h-j}	173^{a-e}	158^{d-h}
Glyphosate + ME (2%)	126	29	52^{klm}	61^{i-m}	909^{b}	145^{e-i}	125^{h-j}	197^{a-c}
Glyphosate + AE (2%)	96	16	173^{fg}	131^{g-i}	1352^{a}	170^{a-f}	162^{c-g}	203^{ab}
Glyphosate + silicon (0.4%)	135	20	78^{h-m}	53^{j-m}	368^{d}	176^{a-e}	172^{a-f}	188^{a-d}
Glyphosate + TritonX100 (0.05%)	99	22	29^{1e}	217^{f}	390^{d}	167^{b-f}	140^{e-i}	204^{a}
LSD (P=0.05)	NS	NS			71.5			36.4

ME and AE indicates methane and aqueous extract of *Sapindus emarginatus*.

In a column, the figures followed by same alphabet do not differ significantly.

Interestingly, *C. rotundus* foliage had maximum spread with TX200 118% when sprayed with 0.8 mm nozzle compared to other species (Table 1). Maximum spread led to more entry points and maximum ^{14}C-glyphosate entry (56.9%) in *C. rotundus* than other species (Fig.1) since droplet evaporation time was same in all species with or without TX200 (Table 2). Whereas, on *L. mollis* and *D. marginata,* spread of droplet with TX200 was same (33 and 38%, respectively), but drop evaporation period was faster on *L. mollis* (66%) than *D. marginata*. Thus per cent dried out deposit with fine drops + TX 200 was 50.2% on *L. mollis* than 11.7 on *D. marginata*. Thus spreading on the *C. rotundus* and prolonged evaporation on *D.marginata* foliage drastically reduced the dried deposition on these weeds foliage than *L. mollis*.

TritonX 100 or 200 is not available in all places therefore, an attempt was made to use the extract of soapnut fruit (*Sapinduse marginatus*) to assess its ability to enhance enrty and translocation of radioactive glyphosate in *O. latifolia*. Relatively low radioactivity was recorded in dried deposit at fed spot of glyphosate with aqueous extract of soap nut fruit and significantly increased glyphosate in fed leaf and bulbs compared to glyphosate alone. This treatment was on par with TritonX 100 (Table 3). Soapnut fruit is easily available to the farmers at all places. Soapnut fruit extract acts as bio-surfactant, antioxidant and better Fe^{2+} chelating agent than tocopherol and ascorbic acid, (Sirkanth and Muralidharan 2010). Thus combination of adjuvants, jaggery and aqueous extract of soapnut fruit seems to be beneficial in aid entry and translocation of foliar herbicides and its efficacy.

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Effect of different herbicides on weed growth and yield performance of wheat

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ABSTRACT

A field experiment was conducted at Chatha, Jammu during winter season of 2004-05 and 2005-06 to study the effect of different herbicides and its mixtures on weeds and yield of wheat (*Triticum aestivum*). Unchecked weeds growth caused 40.3% reduction in grain yield of wheat. Application of sulfosulfuron (25 g) + 2,4-D (500 g/ha) reduced weed population and biomass significantly and thereby caused increase in crop growth and grain yield of wheat. This was at par with tank-mix application of clodinafop (60 g) + metsulfuron-methyl (2 g/ha), isoproturon (750 g) +2,4-D (500 g/ha) and fenoxaprop (120 g) + metribuzin (100 g/ha). Maximum grain yield was recorded in weed-free (5.05 t/ha), but the highest B:C ratio was observed with isoproturon+2,4-D (1.79). There was a significant positive correlation between N uptake by crop and grain yield of wheat (0.99), but a negative correlation was observed between grain yield and density and N removal by weeds.

Key words: Correlation coefficient, Crop growth, Grain yield, Herbicide mixture, Weeds, Wheat

In Jammu and Kashmir, wheat (*Triticum aestivum* L.) is grown on 0.28 mha with an average productivity of 1.82 t/ha (Anonymous 2006). Weeds are one of the major constraint causing yield losses to the extent of 50% (Azad 2003). The crop is infested with heavy population of *Phalaris minor*, *Avena ludoviciana*, *Chenopodium album*, *Vicia sativa* and *Melilotus indica*. Due to continuous use of isoproturon, *Phalaris minor* has become resistant to this herbicide (Malik and Singh 1995). New herbicides such as sulfosulfuron and clodinafop-propargyl have shown high efficacy against grasses in wheat (Singh *et al*. 2003). The knowledge of residual effect of any herbicide formulation in cropping system is of utmost importance because the left-over residues of a herbicide treatment may affect the succeeding crop. Hence, a comprehensive study was undertaken to keep the weeds below threshold level and assess the effect of different herbicide mixtures on crop growth and yield performance of wheat.

MATERIALS AND METHODS

A field experiment was conducted during winter season of 2004-2005 and 2005-2006 at the Research Farm, Chatha of the Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (32^0 40' N latitude and 74^0 58' E longitude at an altitude of 332 m above mean sea level). Soil of the experimental field was low in organic C (0.48%) and available N (210 kg/ha), medium in available P (15.5 kg/ha) and K (135 kg/ha) and neutral in pH (7.1). Treatments consisting of weedy check, weed-free, isoproturon, sulfosulfuron, clodinafop, fenoxaprop-p-ethyl, 2,4-D, metsulfuron-methyl, metribuzin and their combinations were arranged in a randomized block design with 3 replications. Herbicides were sprayed by knapsack sprayer fitted with flat fan T-jet nozzle using a spray volume of 500 l/ha of water 30 days after sowing (DAS). Wheat *cv*. '*PBW-343*' was sown in first week of November in rows 20 cm apart using 100 kg seed/ha. Recommended doses of 100 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha were uniformly applied. Full dose of P and K, and half N were applied as basal at the time of sowing, whereas rest of the N was given in two equal splits as top dressing at 22 days after sowing at crown root initiation stage and 105 days after sowing at booting. Crop was raised under irrigated condition. Observations on weed composition and dry matter were recorded from 2 random quadrat of 0.25 m^2 in each plot at 90 DAS. Weed control efficiency was calculated based on weed dry weight under different treatments. For economic analysis, cost of cultivation, net returns and B:C ratio were computed. Correlation of grain yield with weed parameters and yield attributes was calculated using SPSS 5 software.

RESULTS AND DISCUSSION

Weed population and dry weight

The experimental field was infested with broadleaved weeds, *viz.*, *Trachyspermum* sp., *Anagallis arvensis*, *Eu-*

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phorbia helioscopia, *Medicago denticulata*, *Melilotus indica*, *Vicia sativa*, *Chenopodium album*, *Rumex maritimus*, *Lathyrus aphaca*, *Fumaria parviflora* and *Cirsium arvense*, while the grassy weeds were *Poa annua*, *Phalaris minor* and *Avena ludoviciana*. Maximum weed population and dry weed biomass was recorded in weedy check. Application of tank mixture of sulfosulfuron + 2,4-D was found at par with fenoxaprop + metribuzin, clodinafop + metsulfuron and isoproturon + 2,4-D as well as single application of metribuzin in reducing total weed population and dry weight at 90 DAS compared with weedy check (Table 1). Application of isoproturon and sulfosulfuron also proved equally effective in reducing weed biomass. Accordingly, maximum weed control efficiency was observed with sulfosulfuron + 2,4-D (93.2%), followed by metribuzin alone (91.5-93.1%), isoproturon + 2,4-D (90.8%) and clodinafop + metsulfuron (90.6%).

Crop growth and yield

Tank-mix of sulfosulfuron + 2,4-D, isoproturon + 2,4-D, clodinafop + metsulfuron and fenoxaprop + metribuzin besides alone application of isoproturon and sulfosulfuron resulted in significant increase in dry matter production of wheat compared with weedy check (Table 2). Similarly, tank-mix application of sulfosulfuron + 2,4-D increased leaf area index significantly and was at par with fenoxaprop + metribuzin, isoproturon + 2,4-D, clodinafop + metsulfuron or alone application of sulfosulfuron and isoproturon. Maximum crop growth rate was observed in weed-free plots. Tank-mix application of sulfosulfuron + 2,4-D resulted in significant increase in crop growth rate at par with fenoxaprop + metribuzin, isoproturon + 2,4-D, clodinafop + metsulfuron or alone application of sulfosulfuron at 60-90 DAS. Net assimilation rate showed a decreasing trend between 60-90 DAS but increased thereafter up to 120 DAS. There was no significant effect on net assimilation rate due to different treatments.

Application of sulfosulfuron + 2,4-D, fenoxaprop + metribuzin, isoproturon + 2,4-D and clodinafop + metsulfuron and metribuzin increased number of grains/ear, whereas isoproturon and sulfosulfuron proved equally effective in increasing the number of spikes/m row length, and grain and straw yield of wheat significantly over weedy check. This was because of significant reduction in weed population and biomass, which enhanced N uptake over weedy check. Significantly higher harvest index was observed with all herbicides, whereas lower weed index was recorded with sulfosulfuron + 2,4-D, followed by isoproturon + 2,4-D and clodinafop + metsulfuron. Similar findings were reported by Singh *et al.* (1998) and Singh *et al.* (2003).

Table 1. Population and dry weight of weeds as influenced by various herbicides (pooled data of 2 years)

Treatment	Total weed population at 90 DAS (no./m^2)	Total weed dry weight at 90 DAS (g/m^2)	N-uptake weeds (kg/ha)	N-uptake by wheat (kg/ha)	Weed control efficiency at 90 DAS (%)
Weedy check	18.9 (360.0)	11.8 (140.5)	6.0 (35.9)	75.1	0.0
Weed free	0.71 (0.0)	0.7 (0.0)	0.7 (0.0)	123.2	100.0
Isoproturon 1000 g/ha	9.1 (82.3)	4.5 (20.2)	3.1 (9.2)	105.8	85.6
Sulfosulfuron 25 g/ha	8.0 (63.8)	4.3 (18.9)	2.5 (6.1)	108.8	86.6
Clodinafop 60 g/ha	11.8 (139.8)	7.4 (55.8)	5.4 (29.0)	92.2	60.4
Fenoxaprop 120 g/ha	11.1 (123.5)	7.5 (56.0)	5.4 (29.1)	100.5	60.2
2,4-D 750 g/ha	13.4 (180.1)	9.4 (87.7)	2.2 (4.8)	97.8	37.4
Metsulfuron-methyl 4 g/ha	12.6 (160.8)	9.3 (86.7)	2.1 (4.7)	100.3	38.1
Metribuzin 175 g/ha	6.7 (44.7)	3.5 (12.6)	2.0 (3.5)	104.6	91.5
Metribuzin 200 g/ha	5.8 (34.0)	3.1 (9.8)	1.8 (2.8)	103.7	93.1
Sulfosulfuron + 2,4-D 25 + 500 g/ha	5.9 (35.2)	3.1 (9.6)	1.4 (1.6)	116.2	93.2
Isoproturon + 2,4-D 750 + 600 g/ha	7.0 (49.0)	3.6 (12.9)	1.7 (2.8)	114.0	90.8
Clodinafop + 2,4-D 60 + 500 g/ha	13.1 (172.8)	9.7 (95.2)	3.3 (11.7)	98.5	32.1
Clodinafop + metsulfuron 60 + 2 g/ha	6.2 (38.0)	3.7 (13.4)	1.7 (2.6)	111.8	90.5
Fenoxaprop + metribuzin 120 + 100 g/ha	6.1 (37.3)	3.9 (15.0)	2.3 (5.8)	111.4	89.1
LSD (P=0.05)	1.6	1.6	0.8	9.2	

Data subjected to ($\sqrt{x+0.5}$) transformation, and figures in parentheses are original values

Table 2. Growth and yield attributes of wheat as influenced by various herbicides (pooled data for 2 years)

Treatment	LAI at 90 DAS	Crop growth rate at 60-90 DAS (g/day)	Net assimilation rate at 60-90 DAS (g/cm^2/day)	Spikes /m	Grains /spike	1000-grain weight	Grain yield (t/ha)	Straw yield (t/ha)	Weed index (%)	Harvest index (%)
Weedy check	3.03	1.53	1.18							
Weed free	4.58	2.31	1.18	68.2	43.8	41.8	5.05	8.64	-	36.9
Isoproturon 1000 g/ha	4.20	2.04	1.18	61.5	38.0	39.7	4.32	8.14	14.6	34.6
Sulfosulfuron 25 g/ha	4.37	2.14	1.14	62.5	39.3	39.8	4.49	8.20	11.1	35.3
Clodinafop 60 g/ha	3.80	1.82	1.14	55.0	35.3	37.5	3.88	7.62	23.2	33.7
Fenoxaprop 120 g/ha	3.91	1.90	1.16	59.5	36.1	38.2	4.18	7.85	17.3	34.7
2,4-D 750 g/ha	3.84	1.87	1.16	57.9	35.3	37.7	4.03	7.76	20.3	34.1
Metsulfuron-methyl 4 g/ha	3.89	1.90	1.16	59.5	35.7	38.6	4.16	7.86	17.6	34.6
Metribuzin 175 g/ha	3.93	2.05	1.24	59.0	39.2	40.6	4.23	7.97	14.9	35.0
Metribuzin 200 g/ha	3.92	2.05	1.25	56.3	37.6	40.5	4.25	7.96	15.9	34.7
Sulfosulfuron + 2,4-D 25+500 g/ha	4.48	2.25	1.17	66.2	41.6	40.3	4.78	8.45	5.3	36.1
Isoproturon + 2,4-D 750 + 600 g/ha	4.40	2.19	1.16	65.5	40.6	40.0	4.66	8.40	7.8	35.7
Clodinafop + 2,4-D 60 + 500 g/ha	3.81	1.84	1.14	56.0	35.0	37.7	4.02	7.72	20.4	34.2
Clodinafop+metsulfuron 60 + 2 g/ha	4.45	2.22	1.12	64.5	41.0	40.2	4.67	8.28	7.6	36.0
Fenoxaprop+metribuzin 120 + 100 g/ha	4.23	2.17	1.19	63.8	40.6	40.1	4.52	8.29	10.5	35.3
LSD (P=0.05)	0.54	0.15	NS	5.6	5.1	0.9	0.51	0.39		2.7

Table 3. Correlation coefficient between different growth and yield attributes of wheat and weeds (based on mean of 2 years)

Parameter	CGR 60-90 DAS	NAR 60-90 DAS	Spikes /m	Grains /spike	1000-grain weight	Weed density at 90 DAS	N-uptake by weeds	N-uptake by crop	Straw yield	Grain yield
Dry matter accumulation	0.885*	0.105	0.948*	0.966*	0.889*	-0.885*	-0.758*	0.986*	0.971*	0.989*
CGR at 60-90 DAS	-	0.494*	0.859*	0.900*	0.731*	0.825*	-0.621	0.899*	0.926*	0.902*
NAR at 60-90 DAS	-	-	0.088	0.183	0.025	-0.182	-0.010	0.161	0.2380	0.144
Spikes/m	-	-	-	0.924*	0.769*	-0.760*	-0.660*	0.952*	0.940*	0.947*
Grains/spike	-	-	-	-	0.865*	-0.875*	-0.703*	0.958*	0.948*	0.953*
1000-grain weight	-	-	-	-	-	-0.941*	-0.813	0.878*	0.828*	0.884*
Weed density at 90 DAS	-	-	-	-	-	-	0.710*	-0.876*	-0.861*	-0.892*
N-uptake by weeds	-	-	-	-	-	-	-	-0.752*	-0.697*	-0.744*
N-uptake by crop	-	-	-	-	-	-	-	-	0.982*	0.993*
Straw yield	-	-	-	-	-	-	-	-	-	0.977*

*Significant at P=0.05

Nitrogen uptake by weeds and wheat

Tank-mix application of sulfosulfuron + 2,4-D was at par with fenoxaprop + metribuzin, isoproturon + 2,4-D, clodinafop + metsulfuron and single application of metribuzin, 2,4-D and metsulfuron-methyl resulted in significant reduction in N removal by weeds at harvest (Table 1). This was due to lower weed dry biomass as a result of significant weed control by these herbicides. Singh *et al.* (2003) also reported similar findings. On the other hand, application of sulfosulfuron + 2,4-D, fenoxaprop +

metribuzin, isoproturon + 2,4-D and clodinafop + metsulfuron besides alone application of sulfosulfuron resulted in significant increase in N uptake of wheat compared with weedy check. This was due to lower weed dry weight as a result of significant control of the weeds by these herbicides, which made more N available to the crop (Azad 1997).

Correlation studies

All growth parameters and yield attributes of wheat had significantly positive correlation with grain yield but weed density and N-uptake by weeds were negatively correlated (Table 3). Highest positive correlation was recorded between N-uptake by crop and grain yield of wheat (0.993*). Grain yield also had positive relationship with dry matter accumulation of crop (0.989*), straw yield (0.977*), grain/ear (0.953*), effective tillers/m (0.947*), crop growth rate (0.902*). The correlation coefficient was negative between grain yield and weed density at 60 DAS (-0.892*), 90 DAS (-0.892*) and N-uptake by weeds at harvest (-0.744*).

It was concluded that tank-mix application of sulfosulfuron + 2,4-D, Isoproturon + 2,4-D, clodinafop + metsulfuron, fenoxaprop + metribuzin or alone application of isoproturon and sulfosulfuron were best best treatments for control of weeds in wheat.

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Weed dynamics, nutrient removal and yield of wheat as influenced by weed management practices under valley conditions of Uttarakhand

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ABSTRACT

A field experiment was conducted during *Rabi* seasons of 2006-07 and 2007-08 at Research Farm of GBPUA&T, Krishi Vigyan Kendra Dhakrani, Dehradun to study the effect of weed control practices on weed dyanamics, nutrient uptake and yield of wheat (*Triticum aestivum* (L.) emend. Fiori and Paol). Results revealed that application of clodinafop-propargyl + metsulfuron-methyl (60+4 g/ha) being on at par with clodinafop propargyl + 2,4-D (60+500 g/ha) reduced the weed population significantly over weedy check (97.2%) and other weed control treatments. Clodinafop-propargyl+ metsulfuron-methyl (60+4 g/ha) applied as post-emergence (35 DAS) recorded 14.3, 15.5, 23.7, 29.5, 45.9, 47.4 and 69.7 per cent more grain yield over pendimethalin, isoproturon + metsulfosulfuron-methyl, fenoxaprop-p-ethyl + metsulfuron-methyl, fenoxaprop-p-ethyl, isoproturon, clodinafop-propargyl and weedy check, respectively. The weeds removed the 28.7 kg of N, 13.4 kg P_2O_5 and 21.5 kg of K_2O/ha, and reduced the wheat grain yield by 78.8% as compare to weed free conditions. Application of clodinafop-propargyl + metsulfuron-methyl reduced the nutrients removal by weeds and increased its removal by wheat.

Key words: Herbicides, Nutrient uptake, Weed density, Weed dry matter, Wheat, Yield

Weed infestation is one of the most serious problems in wheat growing areas. Weed competition during the crop period results in more than 53% reduction in grain yield depending on the weed densities and type of weed flora. It has been proved that due to continuous use of isoproturon for the control of Phalaris minor the major weed of wheat has developed the resistance Researches revealed that wheat weeds especially *Phalaris. minor* has developed resistance. Herbicides like clodinafop-propargyl, fenoxaprop-p-ethyl and sulfosulfuron have been recommended as an alternative to isoproturon and metsulfuron-methyl to 2,4-D. Clodinafop-propargyl and fenoxaprop-p-ethyl have been very effective against *Phalaris minor* and *Avena fatua* (Banga and Yadav 2004, Mahajan *et al.* 2004) but ineffective against non grassy weeds. Use of these herbicides has resulted in proliferation of non grassy weeds like *Chenopodium album*, *Melilotus* spp. and *Fumaria parviflora* in wheat (Singh and Singh 2005). Metsulfuron-methyl and 2,4-D are being used commonly for the control of non grassy weeds in wheat. Therefore, it was felt necessary to screen out compatible/suitable herbicides combination for broad-spectrum weed control in wheat.

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MATERIALS AND METHODS

The field experiment was conducted at the GBPUA&T, Krishi Vigyan Kendra, Dhakrani, Dehradun during *Rabi* seasons of 2006-07 and 2007-08. The soil was loamy sand in texture having pH 7.2, organic carbon 0.52%, available P 14.2 kg/ha and available K 168 kg/ha. Twelve treatments comprising pendimethalin at 1000 g/ha, isoproturon at 1000 g/ha, isoproturon + 2,4-D at 1000+500 g/ha, isoproturon + metsulfuron-methyl at 1000+4 g/ha, fenoxaprop-p-ethyl at 80 g/ha, fenoxaprop-p-ethyl + 2,4-D at 80+500 g/ha, fenoxaprop-p-ethyl + metsulfuron-methyl at 80+4 g/ha, clodinafop-propargyl at 60 g/ha, clodinafop-propargyl + 2,4-D at 60+500 g/ha and clodinafop-propargyl + metsulfuron-methyl at 60+4 g/ha along with weed free and weedy check were replicated thrice in a randomized block design. Wheat (*PBW-343*) was sown in row 22 cm apart during 2^{nd} fortnight of November in both the years with the help of ferti-seed drill using 120 kg seed/ha. Crop was fertilized with 120: 60: 40 and 20 kg/ha of N, P_2O_5, K_2O and Zinc sulphate respectively. One third of N and full dose of P, K and Zn were applied as basal at the time of sowing. Remaining N was top dressed in 2 equal splits one after 1^{st} irrigation and second at the time of maximum tillering stage ensuring appropriate moisture level in the field. The herbicides were applied as post-emergence at 35 days after sowing (DAS) using 500 litres water with knapsack sprayer fitted with flat-fan nozzle. However, pendimethalin was applied as pre-emergence at 01 DAS. The crop was raised under irrigated condition with recommended package of practices. Density, dry matter and NPK uptake by weeds were recorded at 60 DAS. The data so obtained were transformed using square root transformation prior to analysis, wherever needed.

RESULTS AND DISCUSSION

Weed flora

The weed flora observed in the experimental plots included *Chenopodium album* L., *Fumeria parviflora* Lam. *Melilotus indica* L. and *Anagallis arvensis* L. among broad leaf weeds; and *Phalaris minor* (L) Retz. and *Avena fatua* L. among annual grasses besides *Cyperus spp*. among sedges. *Phalaris minor* was the dominant (41.3%) among grassy whereas, *Fumeria parviflora* (10.0%) under non grassy weeds.

Weed population and dry matter

The weed control treatments significantly reduced the density and dry biomass of weeds than weedy check (Table 1). Tank mixture of clodinafop-propargyl + metsulfuron-methyl (60+4 g/ha) and clodinafop-propargyl + 2,4-D (60+500 g/ha) proved most effective herbicide combination against both broad-leaved weeds and grasses.

Table 1. Effect of weed management treatments on weed density and weed dry matter in wheat (mean of 2 years)

Treatment	Dose (g/ha)	Application stage (DAS)	*Phalaris minor*	*Avena fatua*	*Chenopodium album*	*Fumaria parviflora*	Others	Total
Weed density (no./m²)								
Weedy	-	-	6.73 (45)	2.73 (7)	3.08(9)	3.24(10)	5.77(38)	11.2(109)
Weed free	-	-	0.70 (0)	0.70(0)	0.70(0)	0.70(0)	0.70(0)	0.70(0)
Pendimethalin	1000	1	3.38 (11)	0.70(0)	1.22(1)	2.34(5)	2.11(4)	4.60(21)
Isoproturon	1000	35	3.24 (10)	1.21(1)	1.58(2)	2.34(5)	3.65(13)	5.68(31)
Isoproturon+2,4-D	1000+500	35	3.08 (9)	1.58(2)	0.70(0)	0.70(0)	1.58(2)	3.67(13)
Isoproturon + metsulfuron-methyl	1000+4	35	3.38(11)	1.58(2)	1.22(1)	0.70(0)	2.73(7)	4.62(22)
Fenoxa prop-p-ethyl	80	35	3.24(10)	1.84(3)	1.84(3)	3.24(10)	5.30(27)	7.31(53)
Fenoxa prop-p-ethyl +2,4-D	80+500	35	3.38(11)	1.22(1)	1.22(1)	0.70(0)	1.58(2)	3.67(13)
Fenoxa prop-p-ethyl + metsulfuron- methyl	80+4	35	2.73(7)	1.55(2)	1.22(1)	0.70(0)	2.55(6)	3.24(10)
Clodinafop -propargyl	60	35	3.23(90)	1.55(2)	1.84(3)	2.34(5)	5.54(35)	7.41(54)
Clodinafop-propargyl + 2,4-D	60+500	35	2.91(8)	1.22(1)	0.70(0)	0.70(0)	0.70(0)	3.08(9)
Clodinafop-propargyl + metsulfuron methyl	60+4	35	2.55(6)	0.70(0)	0.70(0)	0.70(0)	0.70(0)	2.55(6)
LSD (P=0.05)			0.4	0.37	0.14	0.12	0.16	0.48
Weed dry matter (g/m²)								
Weedy	-	-	3.57(12.3)	3.71(13.2)	2.54(6.0)	4.03(15.8)	5.32 (28.6)	9.72(75.7)
Weed free	-	-	0.70(0)	0.70(0)	0.70(0)	0.70(0)	0.70(0)	0.70(0)
Pendimethalin	1000	1	3.10(8.5)	0.70 (0)	1.04(0.6)	2.88(7.8)	3.01 (8.7)	4.72(22.6)
Isoproturon	1000	35	2.22(4.5)	1.3 (1.2)	1.58(2.0)	3.20(9.8)	4.62(22.2)	6.31(39.7)
Isoproturon + 2,4-D	1000+500	35	3.10(8.5)	2.06 (2.8)	0.7(0)	0.70(0)	2.14(4.3)	3.98(15.6)
Isoproturon + metsulfuron methyl	1000+4	35	3.15(8.6)	1.86 (3.0)	1.22(1.0)	0.70(0)	3.95(15.2)	4.78(27.8)
Fenoxa prop-p-ethyl	80	35	1.96 (3.3)	2.18 (4.3)	2.34 (5.0)	4.21(15.0)	4.79(24.5)	5.58(34.1)
Fenoxa prop-p-ethyl +2,4-D	80+500	35	2.98 (8.4)	1.45 (1.6)	0.7(0)	0.70(0)	3.48(11.7)	4.67(21.7)
Fenoxa prop-p-ethyl + metsulfuron-methyl	80+4	35	3.50(11.8)	1.73 (2.5)	1.13(0.8)	0.70(0)	4.13 (16.8)	5.36(31.9)
Clodinafop-propargyl	60	35	1.91(2.3)	1.70 (2.4)	2.24(4.8)	3.72 (13.8)	5.63 (30.7)	7.41 (55.5)
Clodinafop-propargyl + 2,4-D	60+500	35	3.54 (12.1)	1.45 (1.6)	0.7(0)	0.70(0)	0.70(0)	3.70 (13.7)
Clodinafop-propargyl + metsulfuron methyl	60+4	35	3.5 (11.6)	0.70 (0)	0.7(0)	0.70(0)	0.70(0)	3.51 (11.6)
LSD (P=0.05)			0.34	0.25	0.18	0.18	0.22	0.33

*Original values in parentheses

Among the herbicides application of clodinafop-propargyl + metsulfuron-methyl (60+4 g/ha) though statistically on par with clodinafop-propargyl + 2,4-D (60+500 g/ha) reduced the weed population significantly than weed check (97.2%), clodinafop-propargyl alone (88.0%), fenoxa prop-p-ethyl alone (83.0%), isoproturon alone (80.0%), isoproturon + metsulfuron-methyl (72.2%), pendimethalin (71.4%), isoproturon + 2,4-D (53.8%), fenoxaprop-p-ethyl + 2,4-D (53.8%) and fenoxaprop-p-ethyl + metsulfuron-methyl (40.0%) at 60 days after sowing stage. A similar trend was observed with all the applied herbicides with respect to reduction in dry weight of weeds. The reduction in weed population as well as dry matter may be due to the fact that clodinafop-propargyl along with 2,4-D and metsulfuron-methyl may have acted synergistically in broadening the efficacy against variety of weed flora. Similar results werer also obtained by Singh *et al.* (2003), Punia *et al.* (2004) and Bharat and Kachroo (2007).

Weed control efficiency

Maximum weed control efficiency of 84.7% was observed (Table 2) with the application of clodinafop-propargyl + metsulfuron-methyl (60+4 g/ha) followed by clodinafop-propargyl + 2,4-D (81.9%). The lowest weed control efficiency (26.7%) was recorded when clodinafop-propargyl (60g/ha) was applied alone. Higher weed control efficiency with clodinafop-propargyl + metsulfuron-methyl (60+4 g/ha) may be attributed to the better weed control resulting in lower dry weight of weeds.

Yield and weed index

Herbicide application had significant effect on wheat grain and straw yield (Table 2). The highest grain yield of wheat (4.72 t/ha) was recorded in weed free plot which might have resulted in increased nutrients, water, space and light supply to the wheat crop with zero crop-weed competition. This might have resulted in greater photosynthesis and translocation of photosynthates besides longer and stronger sink size as reflected by maximum values of yield attributes and finally the yield. Among the herbicides clodinafop-propargyl + metsulfuron-methyl (60+4 g/ha) applied as post-emergence produced 14.3, 15.5, 23.7, 29.5, 45.9, 47.4 and 69.7 per cent increased grain yield over pendimethalin, isoproturon + metsulfosulfuron-methyl, fenoxaprop-p-ethyl + metsulfosulfuron-methyl, fenoxaprop-p-ethyl, isoproturon, clodinafop-propargyl and weedy check, respectively. Pendimethalin (1000 g/ha) and isoproturon (1000 g/ha) alone or in combination with metsulfuron-methyl (4 g/ha), fenoxaprop-p-ethyl alone (80 g/ha) and in combination with metsulfuron-methyl (4 g/ha) and clodinafop-propargyl alone (60 g/ha) being on a par with each other,

Table 2. Effect of weed control treatments on wheat yield, weed control efficiency, weed index and economics

Treatment	Dose (g/ha)	Yield (t/ha) 2006-07 Grain	2006-07 Straw	2007-08 Grain	2007-08 Straw	Pooled yield (t/ha) Grain	Pooled yield Straw	WCE (%)	WI (%)	Net returns (₹/ha)	B:C ratio
Weedy	-	2.16	3.10	3.12	3.90	2.64	3.50	-	44.1	11,440	1.64
Weed free	-	4.11	5.42	5.33	6.86	4.72	6.14	-	-	27,800	2.13
Pendimethalin	1000	3.24	4.56	4.60	5.72	3.92	5.14	70.1	16.9	23,600	2.18
Isoproturon	1000	2.98	3.66	3.16	4.46	3.07	4.06	47.6	35.0	15,215	1.80
Isoproturon+2,4-D	1000+500	3.98	5.07	4.44	5.75	4.21	5.41	79.4	10.8	27,105	2.39
Isoproturon+metsulfuron-methyl	1000+4	3.24	4.64	4.52	5.44	3.88	5.04	63.3	17.8	23,560	2.21
Fenoxaprop-p-ethyl	80	3.09	4.02	3.83	4.86	3.46	4.44	55.0	26.7	18,790	1.96
Fenoxaprop-p-ethyl +2,4-D	80+500	4.01	5.07	4.31	6.57	4.16	5.82	71.3	11.9	27,200	2.37
Fenoxaprop-p-ethyl +metsulfuron methyl	80+4	3.21	4.66	4.03	5.54	3.62	5.10	57.9	23.3	21,470	2.10
Clodinafoppropargyl	60	2.98	4.06	3.1	4.42	3.04	4.24	26.7	35.6	15,020	1.78
Clodinafop propargyl + 2,4-D	60+500	4.06	5.13	4.48	5.99	4.27	5.56	81.9	9.5	27,915	2.43
Clodinafoppropargyl + metsulfuron-methyl	60+4	4.13	5.37	4.83	6.39	4.48	5.88	84.7	5.1	30,340	2.56
LSD (P=0.05)		0.38	0.32	0.52	0.42	0.52	0.40	-	-		

Table 3. Effect of weed control treatments on nutrient removal by wheat and associated weeds

Treatment	Dose (g/ha)	Nutrient removal by wheat (kg/ha)			Nutrient removal by weeds* (kg/ha)		
		N	P	K	N	P	K
Weedy	-	98.4	15.8	95.6	5.40(28.7)	3.77(13.4)	4.62(21.5)
Weed free	-	114.7	23.7	118.2	0.70(00.0)	0.70(0.0)	0.70(00.0)
Pendimethalin	1000	108	19.8	109.8	4.01(15.6)	2.87(7.8)	3.64(12.8)
Isoproturon	1000	104.6	17.8	107.5	4.43(19.2)	3.11(9.2)	3.78(13.8)
Isoproturon + 2,4-D	1000+500	110.8	20.9	115.7	3.63(12.4)	2.86(7.7)	3.33(10.6)
Isoproturon + metsulfuron-methyl	1000+4	106.7	19.2	111.3	4.22(17.4)	3.08(9.0)	3.66(12.6)
Fenoxaprop-p-ethyl	80	104.9	19.3	107.4	4.32(18.2)	3.21(9.8)	3.75(13.6)
Fenoxaprop-p-ethyl +2,4-D	80+500	109.6	20.4	115.2	3.68(12.8)	3.02(8.7)	3.58(12.3)
Fenoxapropp-ethyl + metsulfuron-methyl	80+4	105.3	19.5	108	4.30(17.8)	3.14(9.4)	3.66(12.9)
Clodinafop-propargyl	60	102.3	17.5	106.3	4.60(20.4)	3.18(9.6)	3.88(14.6)
Clodinafop-propargyl +2,4-D	60+500	112.6	21.3	116.3	3.46(11.5)	2.77(7.2)	3.48(11.6)
Clodinafop-propargyl + metsulfuron-methyl	60+4	112.1	21.6	116.7	3.40(10.8)	2.82(7.4)	3.27(10.2)
LSD (P=0.05)		5.0	2.0	5.3	0.3	0.28	0.3

*Original values in parentheses

increased the yield of wheat significantly as compared with weedy check. However, herbicide combinations of isoproturon + 2,4-D (1000+500 g/ha), clodinafop-propargyl + 2,4-D (60+500 g/ha), fenoxaprop-p-ethyl + 2,4-D (80+500g/ha) and clodinafop-propargyl + metsulfuron-methyl (60+4 g/ha) yielded similar to that of weed free condition. The similar results have also been reported by Punia *et al.* (2004). The lowest weed index (5.1%) was observed in clodinafop-propargyl + metsulfuron-methyl (60+4 g/ha) followed by clodinafop-propargyl + 2,4-D (9.5%).

NPK depletion by weeds

Maximum removal of NPK by weeds was recorded in weedy check, due to higher dry matter of weeds which enabled them to absorb more nutrients. The minimum depletion of NPK was recorded with herbicide mixture of clodinafop-propargyl + metsulfuron-methyl due to efficient control of weeds (84.7%), which resulted in the lowest weed dry matter (Table 2). Herbicides, *viz.*, pendimethalin, isoproturon, isoproturon + 2,4-D, isoproturon + metsulfuron-methyl, fenoxaprop-p-ethyl , fenoxa prop-p-ethyl + 2,4-D, fenoxa prop-p-ethyl + metsulfuron-methyl, clodinafop-propargyl, clodinafop-propargyl + 2,4-D and clodinafop-propargyl + metsulfuron-methyl depleted 42.5, 33.6, 51.7, 38.7, 34.6, 46.8, 37.0, 30.0, 52.3 and 55.3 % less NPK over weedy check. Singh and Saha (2001) also reported lower nutrient depletion under herbicidal treatments as compared weedy check.

NPK uptake by crop

Significantly higher uptake of NPK by grains and straw of wheat was recorded in weed free conditions compared to the herbicidal treatments except clodinafop-propargyl + metsulfuron-methyl and clodinafop- propargyl + 2,4-D (Table 2) being 8.0, 11.6, 3.7, 8.2, 10.8, 4.6, 10.2 and 13.5 per cent higher over pendimethalin, isoproturon, isoproturon + 2,4-D, isoproturon + metsulfuron-methyl, fenoxaprop-p-ethyl, fenoxaprop-p-ethyl + 2,4-D, fenoxaprop-p-ethyl + metsulfuron-methyl and clodinafop-propargyl + metsulfuron-methyl, respectively. All the herbicidal treatments recorded significantly higher total nutrient uptakes than the weedy check. The lowest nutrient uptake by wheat grains and straw in weedy check seems to be due to the increase in weed dry matter accumulation. The results are similar to the finding of Pandey *et al.* 2001.

Economics

Maximum net returns were obtained with clodinafop-propargyl + metsulfuron-methyl (60 + 4 g/ha) applied at 35 DAS followed by clodinafop-propargyl + 2,4-D. The benefit : cost ratio was followed the trend same as net returns. The unweeded check recorded lowest net return and B:C ratio (Table 2).

It can be concluded that post-emergence application of clodinafop-propargyl + metsulfuron-methyl (60+4 g/ha) effectively reduced weed population and its dry weight and increased the grain yield of wheat.

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Effect of weed management practices on finger millet under rainfed conditions

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ABSTRACT

A field experiment with 11 weed management practices including herbicide and hand weedings was conducted at Jagdalpur during 2006 and 2007. *Digitaria sangunalis, Eleusine indica* and *Echinochloa colona* among monocots, and *Celosia argentia* and *Spilanthes acmella* among dicots were the major weeds. Dry weight of weeds and weed control efficiency were the lowest under weed-free condition throughout crop growth period *fb* weed-free up to 40 and 50 DAS, and hand weedings at 20 and 40 DAS. These treatments also led to higher yield attributes and yields of finger millet. The highest B:C ratio (3.79) was obtained when isoproturon 0.5 kg/ha was applied as pre-emergence followed by its lower dose (0.05 kg/ha).

Keyword: Economics, Fingermillet, Grain yield, Weed-free

Finger millet is grown in a wide range of climatic regions. The crop is quite important in dryland regions and mountain or hill agriculture systems. It is grown under upland situation where weeds infestation coincide with occurrence of rain during rainy season. Initial growth period of finger millet is subjected to infestation of weeds causing higher competition, leading to drastic reduction in yield (Kushwaha *et al*. 2002). There is urgent need to find out an effective and economic method of weed control under rainfed situations. As information available is meager, the present investigation was carried out to find out critical period of weed completion and suitable method of weed control in finger millet.

MATERIALS AND METHODS

An experiment was carried out at S.G. College of Agriculture and Research Station, Jagdalpur during rainy season 2006 and 2007. The soil was medium in available N (260 kg/ha) and P (15 kg/ha), high in available K (290 kg/ha) with pH 6. 5. Finger millet *cv.* '*VR 708*' was sown in the end of June in 30 cm wide rows. Half dose of N (30 kg/ha) alongwith full dose of P and K (40 and 20 kg/ha) were applied as basal, and remaining N (30 kg/ha) was applied as top dressing after 25 days after sowing. Eleven treatments involving weed free at 20, 30, 40, 50 and 60 days after sowing were taken. Isoproturon 0.05 and 0.50 kg/ha was applied as pre-emergence through incorporation into soil. Dry weight was recorded by putting a quadrate (0.25 m^2) at three random spots in each plot at harvest. Weed control efficiency was also calculated on the basis of dry matter production of weeds. Data on growth, yield attributes and economics were recorded and analysed statistically. Weed density data were analysed after square root transformation.

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RESULTS AND DISCUSSION

Weed growth

All weed management practices significantly reduced dry weight of weeds, *viz., Echinochloa colona, Eleusine indica, Digitaria sanguinalis, Celosia argentia* and *Spilanthes acmella*as compared to weedy check. Weedy check registered the highest dry matter of weeds, which was reduced to varying magnitude under different weed management practices. The dry weight of *Echinochloa colona, Eleusine indica, Digitaria sanguinalis, Celosia argentia* and *Spilanthes acmella* was identical under all weed management practices. Weed-free at 60 DAS significantly was superior than weed-free at 20, 30, and 40 DAS, as well as isoproturon 0.05 kg/ha and 0.5 kg/ha (Table 1). Hand weeding at 20 DAS and weed-free upto 20 DAS were similar in terms of dry weight of these weeds. Similar results were reported by Pradhan and Sonboir (2009) and Pradhan *et al.* (2010).Weed control efficiency with weed-free throughout crop period was 89.6-92.6%, which was at par with two hand weeding and weed-free at 20 and 40 DAS. The lowest WCE was recorded under weedy check.

Crop growth and yield

Plant height was maximum when weeds were uprooted completely throughout growing period of finger millet, which was at par with hand weeding twice (20 and 40 DAS) including weed-free condition up to 50 and 60 DAS (Table 2). However, weed free condition at 20, 30

Table 1. Effect of weed management on dry weight (g/m²) of different weed species

Treatment	*Echinochloa colona*		*Eleusine indica*		*Digitaria sanguinalis*		*Celosia argentia*		*Spilanthes acmella*		WCE (%)	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Weed free for 20 DAS	4.6 (21.1)	4.4 (19.0)	4.9 (23.7)	4.7 (21.5)	5.1 (26.2)	2.5 (6.0)	5.4 (28.7)	3.0 (8.5)	5.6 (31.2)	3.4 (11.0)	51.8	43.2
Weed free for 30 DAS	3.8 (14.1)	3.5 (12.0)	3.9 (15.1)	3.6 (13.0)	4.0 (16.1)	2.1 (3.9)	4.2 (17.1)	2.3 (4.9)	4.3 (18.1)	2.5 (5.9)	77.8	65.2
Weed free for 40 DAS	3.1 (9.1)	2.7 (7.0)	2.9 (7.9)	2.5 (5.7)	2.6 (6.6)	2.7 (6.9)	2.4 (5.4)	2.6 (6.7)	2.1 (4.1)	2.3 (5.2)	88.7	82.4
Weed free for 50 DAS	2.5 (6.1)	2.1 (4.0)	2.3 (4.9)	2.0 (3.5)	2.1 (4.2)	1.7 (2.4)	2.6 (6.5)	2.5 (5.9)	2.7 (7.0)	2.8 (7.5)	90.3	86.8
Weed free for 60 DAS	2.2 (4.6)	1.4 (1.6)	1.9 (3.3)	2.2 (4.4)	2.3 (5.1)	1.5 (2.0)	2.7 (6.9)	2.7 (6.9)	2.6 (6.6)	2.8 (7.5)	89.6	85.6
Weed free throughout	2.0 (3.7)	1.4 (1.6)	1.7 (2.5)	1.8 (2.7)	2.0 (3.6)	1.7 (2.4)	1.7 (2.4)	1.8 (3.0)	1.2 (1.1)	2.0 (3.7)	92.5	89.8
Isoproturon 0.05 kg/ha	3.0 (9.0)	2.7 (6.8)	2.8 (7.7)	3.0 (8.7)	3.1 (9.4)	2.8 (7.6)	3.5 (11.7)	3.5 (11.9)	3.5 (12.2)	3.6 (12.8)	83.0	71.6
Isoproturon 0.5 kg/ha	2.5 (5.7)	2.0 (3.6)	2.2 (4.5)	2.4 (5.5)	2.5 (6.2)	2.2 (4.4)	3.0 (8.5)	3.0 (8.7)	3.0 (9.0)	3.1 (9.5)	76.9	81.0
Hand weeding at 20 DAS	2.2 (4.5)	1.7 (2.4)	1.7 (2.5)	2.0 (3.5)	2.1 (4.2)	1.8 (3.0)	2.6 (6.5)	2.6 (6.7)	2.7 (7.0)	2.8 (7.6)	70.6	86.7
Hand weeding at 20 and 40 DAS	2.0 (3.7)	0.8 (1.1)	1.5 (1.7)	1.8 (2.8)	2.0 (3.5)	1.4 (1.6)	2.5 (5.7)	1.9 (3.3)	2.6 (6.2)	2.7 (6.8)	83.1	88.4
Weedy check	6.0 (36.1)	5.8 (34.0)	6.2 (38.7)	6.0 (36.5)	6.4 (41.2)	4.6 (21.0)	6.6 (43.7)	4.9 (23.5)	6.8 (46.2)	5.1 (26.0)	-	-
LSD (P=0.05)	1.3	0.8	0.8	0.9	0.9	0.8	0.7	1.0	1.0	0.9	9.5	3.0

*Figures in parentheses are original values and transformed to square root $\sqrt{(x + 0.5)}$

Table 2. Effect of weed management practices on yield and economics of finger millet

Treatment	Plant height at maturity (cm)		Tillers/plant		Fingers/plant		Grain yield (t/ha)		B:C ratio	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Weed free for 20 DAS	97.0	99.4	2.99	2.74	2.37	2.82	1.76	1.89	2.86	3.07
Weed free for 30 DAS	95.6	98.0	2.26	3.01	3.43	3.88	1.86	1.99	2.42	2.60
Weed free for 40 DAS	105.0	107.7	2.19	2.94	4.40	4.85	1.96	2.12	2.37	2.60
Weed free for 50 DAS	110.7	113.1	4.06	4.81	4.43	4.88	2.06	2.02	2.36	2.62
Weed free for 60 DAS	110.9	113.3	4.96	5.71	4.52	4.97	2.10	2.29	1.75	1.90
Weed free throughout	121.2	123.6	5.49	6.24	4.06	4.51	2.33	2.58	1.52	1.68
Isoproturon 0.05 kg/ha	106.8	109.2	4.05	3.10	3.82	4.27	1.54	1.69	3.55	3.87
Isoproturon 0.5 kg/ha	98.1	100.2	4.36	5.11	4.99	5.44	2.04	2.23	3.79	4.21
Hand weeding at 20 DAS	109.7	112.0	3.63	4.38	2.15	2.60	1.61	1.42	3.42	3.75
Hand weeding at 20 and 40 DAS	110.8	113.2	4.19	4.94	3.98	4.43	2.08	2.28	2.97	3.25
Weedy check	114.1	116.5	2.63	3.38	2.05	2.50	0.56	0.72	1.04	1.35
LSD (P=0.05)	7.2	7.2	0.53	0.55	0.48	0.49	0.25	0.33	-	-

and 40 DAS, and isoproturon 0.05 and 0.5 kg/ha were found comparable with each other due to smothering of weeds, which led to vertical growth rather than horizontal growth of finger millet. Tillers/plant, racemes/plant and 1000-grain weight showed higher values under weed-free throughout crop period, followed by weed condition up to 60 DAS. Pandey *et al.* (2001) found that isoproturon was more effective against grassy and broad-leaved weeds but inferior to hand weeding twice.

Critical period of crop-weed competition in cereals up to 30 days after sowing was advocated by Chandha (1999) and Badgujar *et al*. (2003). Maximum grain yield was recorded when weed-free condition was maintained throughout crop period, which was significantly superior to other treatments except weed-free up to 60 DAS and hand weeding twice. Weed free up to 40 and 50 DAS were found statistically similar but superior to weed free up to 20 and 30 DAS. Suppression of weeds at critical period exerted positive influence on crop growth but later weed flushes hampered the yield attributes and lowered the grain yield. Hence, weed free condition up to harvest gave higher yield than hand weedings at 20 and 40 DAS as well as weed-free up to 60 DAS. Application of isoproturon 0.50 kg/ha resulted in higher grain yield than its lower dose (0.05 kg/ha). The lowest yield was recorded under weedy check. Weed free condition from 20 to 40 DAS did not exert remarkable yield difference and showed equal effect on weed flora.

The highest B:C ratio was obtained when isoproturon was applied 0.50 kg/ha followed by its lower dose (0.05 kg/ha). One hand weeding at 20 DAS also resulted in higher B:C ratio, which was similar to weed free up to 20 DAS. The lowest B:C ratio was recorded under two weeding at 20 and 40 DAS.

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Short communication

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Efficacy of herbicides for weed control in aerobic rice

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In the 21st century along with population pressure, the scarcity of agricultural land, water and shortage of labour maintained pressure for a shift towards direct seeding methods in rice cultivation (Mortimer *et al.* 2005). Aerobic rice systems, wherein the crop is established through direct seeding in non-puddled, non-flooded fields, are among the most promising approaches for saving water (Bhushan *et al.* 2007). Weeds pose a serious threat to the direct seeded aerobic rice by competing for nutrients, light, space and moisture throughout the growing season (Hussain *et al.* 2008). Samar Singh *et al.* (2008a) reported that in aerobic direct seeded rice, loss of grain yield due to weed competition ranged from 38 to 92%. Therefore, the present investigation was undertaken to find out the efficacy of new generation herbicides for broad-spectrum weed control over traditional recommended herbicide in aerobic rice.

Field experiment was conducted at Agricultural College and Research Institute, Madurai during *Rabi* 2010-2011. The investigation was carried out on weed management in aerobic rice with 12 treatments under randomized block design (RBD) with three replications. The test variety of rice was '*ADT 47*'. The weed management treatments imposed were pre-emergence pyrazosulfuron alone (25 g/ha) on 3 DAS (T_1), pre-emergence pretilachlor-S alone (750 ml/ha) on 3 DAS (T_2), post-emergence cyhalofop butyl alone (90 ml/ha) on 25 DAS (T_3), post-emergence fenoxaprop alone (60 ml/ha) on 30 DAS (T_4), post-emergence mixture of cyhalofop butyl + (chlorimuron + metsulfuron) (90 ml + 20 g/ha) on 30 DAS (T_5), post-emergence mixture of fenoxaprop + (chlorimuron + metsulfuron) (60 ml + 20 g/ha) on 30 DAS (T_6), post-emergence azimsulfuron alone (35 g/ha) on 20 DAS (T_7), post-emergence bispyribac sodium alone (25 ml/ha) on 20 DAS (T_8), post-emergence mixture of fenoxaprop + ethoxysulfuron (60 ml + 15 g/ha) on 30 DAS (T_9), sequence application of pre-emergence oxyfluorfen and post-emergence 2,4-D (300 ml + 500 g/ha) on 30 DAS (T_{10}), two hand weeding at 15 and 35 DAS (T_{11}) and unweeded control (T_{12}). The observations on weeds and crop yield were recorded and statistically analysed. The weed density and dry matter production (DMP) were subjected to square root transformation.

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Weed flora

The predominant category of weed was broad leaved weeds followed by grasses and sedges. The weed flora mainly consisted of *Echinochloa colona, Panicum javanicum, Chloris barbata, Dactyloctenium aegyptium* and *Panicum repens* under grasses; *Cyperus iria* under sedges and *Cleome viscosa, Corchorus olitorius, Euphorbia hirta, Merremia emarginata, Portulaca oleracea* and *Trianthema protulacastrum* under broad leaved weeds.

Weed growth

Grass density was significantly reduced by post-emergence mixture of fenoxaprop + (chlorimuron + metsulfuron) on 30 DAS (T_6) significantly to 16.0/m^2. This was followed by sequence application of pre-emergence oxyfluorfen and post-emergence 2,4-D on 30 DAS (T_{10}) and post-emergence mixture of fenoxaprop + ethoxysulfuron on 30 DAS (T_9) with grass density of 18.7 and 22.0/m^2, respectively. But treatment T_9 was comparable with post-emergence bispyribac sodium alone on 20 DAS (T_8).

Sedge weed density was not found in post-emergence application of bispyribac sodium alone on 20 DAS (T_8) as well as sequence application of pre-emergence oxyfluorfen and post-emergence 2,4-D on 30 DAS (T_{10}). This was followed by post-emergence mixture of fenoxaprop + (chlorimuron + metsulfuron) on 30 DAS (T_6) and post-emergence mixture of fenoxaprop + ethoxysulfuron on 30 DAS (T_9) which recorded sedge weed density of 1.0 and 2.3/m^2, respectively.

Broad leaved weed (BLW) density was significantly reduced by post-emergence mixture of fenoxaprop + (chlorimuron + metsulfuron) on 30 DAS (T_6) to 1.00/m^2. This was followed by sequence application of pre-emergence oxyfluorfen and post-emergence 2,4-D on 30 DAS (T_{10}) and post-emergence mixture of fenoxaprop +

ethoxysulfuron on 30 DAS (T_9) with BLW of 1.67 and 2.67/m^2, respectively. Hand weeding twice recorded grass, sedge and BLW density of 28.3, 12.0 and 8.3/m^2, respectively. Unweeded control (T_{12}) recorded higher sedge weed density of 51.24 and 63.28/m^2 at 60 and 90 DAS, respectively.

Post-emergence mixture of fenoxaprop + (chlorimuron + metsulfuron) on 30 DAS (T_6) significantly lowered the total weed density to 18.00/m^2. This was followed by sequence application of pre-emergence oxyfluorfen and post-emergence 2,4-D on 30 DAS (T_{10}) and post-emergence mixture of fenoxaprop + ethoxysulfuron on 30 DAS (T_9). But post-emergence mixture of fenoxaprop + ethoxysulfuron on 30 DAS (T_9) was comparable with post-emergence bispyribac sodium alone on 20 DAS (T_8).

Post-emergence mixture of fenoxaprop + (chlorimuron + metsulfuron) on 30 DAS (T_6) significantly increased the weed control efficiency (WCE). It might be due to the use of mixture of herbicides which showed broad spectrum control of weeds. This is evident from earlier result that fenoxaprop ethyl at 50 g/ha could be used as post-emergence spray for the control of grassy weeds (Samar Singh *et al.* 2008b). Another result with metsulfuron-methyl + chlorimuron-ethyl at 4 g/ha provided excellent control of broad leaved weeds and sedges (Singh and Tewari 2005). However, Purshotam Singh *et al.* (2007) recorded highest weed control efficiency with

Table 1. Effect of new herbicides on weed density, dry weight at 60 DAS and grain yield of aerobic rice

Treatment	*Weed density (no./m^2)				WCE (%)	*Weed dry matter production (kg/ha)				Grain yield (kg/ha)
	Grasses	Sedges	BLWs	Total		Grasses	Sedges	BLWs	Total	
T_1- Pre-emergence pyrazosulfuron alone on 3 DAS	7.31 (53)	3.81 (14)	3.98 (15)	9.10 (82)	70.2	13.17 (173)	3.94 (15)	6.67 (44)	15.24 (232)	3795
T_2- Pre-emergence pretilachlor-S alone on 3 DAS	7.33 (59)	4.06 (16)	4.38 (18)	9.72 (94)	66.0	13.43 (180)	4.30 (18)	8.57 (73)	16.49 (271)	3743
T_3- Post-emergence cyhalofop butyl alone on 25 DAS	6.47 (41)	4.00 (15)	3.89 (14)	8.48 (71)	74.2	12.31 (151)	4.06 (16)	6.52 (42)	14.48 (209)	3860
T_4- Post-emergence penoxapropalonen 30 DAS	5.46 (29)	4.10 (16)	4.14 (16)	7.92 (62)	77.4	8.69 (75)	4.41 (19)	6.74 (45)	11.81 (139)	4065
T_5- Post-emergence mixture of cyhalofopbutyl+chlorimuron + metsulfuron) on 30 DAS	5.85 (34)	3.44 (11)	3.72 (13)	7.67 (58)	78.9	9.08 (82)	2.92 (8)	5.70 (32)	11.06 (122)	4118
T_6- Post-emergence mixture of fenoxaprop + (chlorimuron + metsulfuron) on 30 DAS	4.06 (16)	1.22 (1)	1.22 (1)	4.30 (18)	93.5	6.52 (42)	1.87 (3)	2.92 (8)	7.30 (53)	4345
T_7- Post-emergence azimsulfuron alone on 20DAS	5.08 (25)	1.87 (3)	3.34 (10)	6.28 (39)	85.9	8.22 (67)	2.12 (4)	5.05 (25)	9.80 (96)	5153
T_8- Post-emergence bispyribac sodium alone on 20 DAS	4.81 (22)	0.71 (0)	2.20 (4)	5.24 (27)	90.2	8.09 (65)	0.71 (0)	4.84 (23)	9.40 (88)	5805
T_9- Post-emergence mixture of fenoxaprop + ethoxysulfuron on 30 DAS	4.74 (22)	1.68 (2)	1.78 (2)	5.24 (27)	90.2	7.97 (63)	2.12 (4)	4.53 (20)	9.33 (87)	6278
T_{10}–Pre-emergence oxyfluorfen and post-emergence 2, 4-D on 30 DAS	4.38 (19)	0.71 (0)	1.47 (1)	4.56 (20)	92.6	7.84 (61)	0.71 (0)	4.30 (18)	8.93 (79)	4262
T_{11}-Two hand weeding at 15 and 35 DAS	5.37 (28)	3.54 (12)	2.97 (8)	7.01 (48)	82.4	8.51 (72)	3.08 (9)	4.95 (24)	10.25 (105)	4508
T_{12}-Unweeded control	11.14 (124)	7.19 (51)	10.12 (102)	16.66 (276)	-	21.94 (481)	9.62 (92)	21.53 (463)	32.20 (1036)	2105
LSD (P=0.05)	0.19	0.09	0.11	0.25		0.340	0.10	0.21	0.42	357

*Data subjected to square root transformation; values in parentheses are original metsulfuron-methyl 10% + chlorimuron-ethyl 10% (Almix) 8 g/ha.

Post-emergence mixture of fenoxaprop + (chlorimuron + metsulfuron) on 30 DAS (T_6) provided a broad spectrum of weed control by significantly reducing the dry weight of grass, sedge, BLW and total weeds at 60 DAS. This weed management practice (T_6) was followed by sequential application of pre-emergence oxyfluorfen and post-emergence 2,4-D on 30 DAS (T_{10}) and post-emergence mixture of fenoxaprop + ethoxysulfuron on 30 DAS (T_9). These treatments were found to be superior compared to farmers' practice of hand weeding twice and test chemical of pre-emergence application of pretilachlor (Table 1).

Visual phyto-toxicity on crop

Phyto-toxicity symptom was observed on aerobic rice at 10, 20 days after herbicide spraying and before harvest. The result on phyto-toxicity rating revealed that pre-emergence oxyfluorfen and post-emergence 2,4-D on 30 DAS (T_{10}) showed phyto-toxicity rating of 5 on 10 DAS and 4 on 20 DAS and no toxicity before harvest. This was reported earlier by Kathiresan and Manoharan (2002). All other herbicidal weed management treatments did not exhibit any phyto-toxicity symptoms at any stage of the aerobic rice (Table 2).

Economic yield

Grain yield was significantly improved by weed control treatments compared to unweeded control. Among

Table 2. Visual phyto-toxicity of aerobic rice at 10 and 20 DAS and before harvest

Treatment	Visual phytotoxicity					
	10 DAS	Rating	20 DAS	Rating	Before harvest	Rating
T_1-Pre-emergence pyrazosulfuron alone on 3 DAS	No injury, normal	0	No injury, normal	0	No injury, normal	0
T_2-Pre-emergence pretilachlor-S alone on 3 DAS	No injury, normal	0	No injury, normal	0	No injury, normal	0
T_3-Post-emergence cyhalofop butyl alone n 25 DAS	No injury, normal	0	No injury, normal	0	No injury, normal	0
T_4-Post-emergence penoxapropalonen 30 DAS	No injury, normal	0	No injury, normal	0	No injury, normal	0
T_5-Post-emergence mixture of cyhalofopbutyl+chlorimuron + metsulfuron) on 30 DAS	No injury, normal	0	No injury, normal	0	No injury, normal	0
T_6-Post-emergence mixture of fenoxaprop + (chlorimuron + metsulfuron) on 30 DAS	No injury, normal	0	No injury, normal	0	No injury, normal	0
T_7-Post-emergence azimsulfuron alone on 20DAS	No injury, normal	0	No injury, normal	0	No injury, normal	0
T_8-Post-emergence bispyribac sodium alone on 20 DAS	No injury, normal	0	No injury, normal	0	No injury, normal	0
T_9-Post-emergence mixture of fenoxaprop + ethoxysulfuron on 30 DAS	No injury, normal	0	No injury, normal	0	No injury, normal	0
T_{10}–Pre-emergence oxyfluorfen and post-emergence 2,4-D on 30 DAS	Injury more persistent, recovery doubtful	5	Moderate injury, recovery possible	4	No injury, normal	0
T_{11}-Two hand weeding at 15 and 35 DAS	-	-	-	-	-	-
T_{12}-Unweeded control	-	-	-	-	-	-

different treatments, post-emergence mixture of fenoxaprop + ethoxysulfuron on 30 DAS (T_9) recorded significantly higher grain yield of 6278 kg/ha. Fenoxaprop + ethoxysulfuron 50 +18 g/ha at 21 DAS were found effective in reducing the weeds and improving the yield (Samar Sing *et al.* 2008b). This was followed by post-emergence bispyribac sodium alone on 20 DAS (T_8), post-emergence azimsulfuron alone on 20 DAS (T_7). Unweeded control (T_{12}) recorded very low grain yield of 2105 kg/ha which was 4173 kg/ha lesser than best treatment of post emergence mixture of fenoxaprop + ethoxysulfuron on 30 DAS (T_9) (Table 1).

Fenoxaprop at 0.06 kg/ha mixed with ethoxysulfuron at 0.015 kg/ha as post-emergence showed the lowest weed dry matter, highest weed control efficiency and higher grain yield (Tiwari *et al.* 2010). Similar results of increased yield through effective weed control were also noticed with fenoxaprop-ethyl (Lourens *et al.* 1989) and ethoxysulfuron (Hussain *et al.* 2008).

The post-emergence mixture of fenoxaprop + ethoxysulfuron on 30 DAS (T_9) in aerobic rice was the appropriate weed management practice to control broad spectrum of weed species with minimum grass, sedge, broad-leaved weed and total weed density and their dry matter production and higher weed control efficiency to obtain higher productivity in aerobic rice.

SUMMARY

Field experiment was conducted at Agricultural College and Research Institute, Madurai during *Rabi* 2010-2011 to study the efficacy of new herbicides for controlling weeds in aerobic rice. Minimum grass, sedge, broad leaved weed and total weed density and their dry matter production and higher weed control efficiency were obtained in plots receiving post-emergence mixture of fenoxaprop + (chlorimuron + metsulfuron) on 30 DAS followed by sequential application of pre-emergence oxyfluorfen and post-emergence 2,4-D on 30 DAS and post-emergence mixture of fenoxaprop + ethoxysulfuron on 30 DAS. The result on phyto-toxicity rating revealed that pre-emergence oxyfluorfen and post-emergence 2,4-D on 30 DAS showed phyto-toxicity rating of 5 on 10 DAS and 4 on 20 DAS and no toxicity before harvest. Post-emergence mixture of fenoxaprop + ethoxysulfuron on 30 DAS recorded significantly higher grain yield of 6278 kg/ha.

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Short communication

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Effect of soil solarization on weed seed bank in soil

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Weeds are self grown plants which appear simultaneously with crop plant and result in intense crop-weed competition and cause reduction in yield varying from 27-71% depending upon type and intensity of weeds and their time of occurrence. Effective weed management requires knowledge of weed seed bank dynamics, germination pattern and environmental conditions suitable for seedling emergence (Fraud-William *et al.* 1984). Weed seed bank affects the weed flora and its density because of the good relationship between the weed flora and the weed seed bank in the soil (Sousa *et al*. 2003). Soil solarization is a special technique in which moist soil is covered by polyethylene (PE) film and heated by solar radiation for several weeks. Northern India has high air temperature in summer therefore high soil temperature (50-60^{0}C) can be developed in soil covered with transparent polyethylene sheets (Kumar *et al*. 1993). A field experiment was done to asses the effectiveness of soil solarization for a period of 45 days on weed dynamics in pearl millet-wheat cropping system

An experiment on evaluation of soil solarization on weed seed bank of soil was conducted in summer season of 2004 at Research farm, College of Agriculture, Gwalior. The experiment was laid out in randomized block design with six non-chemical agronomical weed management practices *viz.*, solarized, non-solarized, stale seed bed, deep ploughing, green manuring and mulching by green biomass replicated thrice. For soil solarization, transparent poly ethylene sheets of 30 µm thickness were used. Before spreading the polyethylene sheets to the field, one light irrigation was given to all the plots. The temperature of the soil in each treatment was recorded every day at 10 and 15 cm depth. The polyethylene sheets in the solarized plots were spread, on 18th May 2004 and they were removed on 2nd July 2004 with minimum disturbance.

Soil samples (0-15 cm) were collected from each treatment to find out the weed seed accumulation. After drying and sieving with 2 mm sieve, the soil samples were spread over shallow trays followed by watering to encourage the emergence of weeds. The species wise weed population was recorded 3-4 times after flushes of weed emergence.

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The soil temperatures recorded under solarized conditions were 43.9^{0}C and 43.8^{0}C at 10 and 15 cm depth, respectively and it was 4.6^{0}C and 4.5^{0}C higher than non-solarized soil. The increase in temperature of solarized soil was 1.9–10.4^{0}C and 2.1 to 10.5^{0}C at 10 and 15 cm depth, respectively as compared to different agronomic practices (Table 1). The weeds emerged were, two grassy weeds namely *Echinochloa crusgalli* and *Commelina benghalensis*, four broad leaved weeds *viz., Digera arvensis, Trianthema mongoyna, Chenopodium album* and *Phylanthus niruri* and one sedge *Cyperus rotundus* (Table 2). In general, the number of *E. crusgalli* were highest followed by *C. rotundus* and *C. album*. In solarized soil

Table 1. Mean soil temperature (^{0}C) under different agronomical practices

Agronomic practice	Temperature (^{0}C) at depth	
	10 cm	15 cm
Solarized	43.9	43.8
Non-solarized	39.3	39.3
Stale seed bed	38.0	37.8
Deep ploughing	42.0	41.7
Green manuring	36.8	36.7
Mulching by weeds	33.5	33.3
Increase in temperature of solarized vs non-solarized	4.6	4.5
Increase in temperature of solarized vs other practices	1.9-10.4	2.1-10.5

total number of grassy, broad leaved and sedges weeds was lowest, while highest grasses were reported in non-solarised soil. Total numbers of weeds were highest in non-solarized soil followed by green manuring, stale seed bed, mulching, deep ploughing and solarized soil. The factors involved in soil solarization are soil temperature, moisture and probably gases (Horowitz *et al*. 1983). High temperature may cause damaging changes in enzyme activity,

Table 2. Weed seed bank in soil after solarization and other agronomical practices (no./100 g soil)

Weeds	Solarized	Non-solarized	Stale seed bed	Deep ploughing	Green manuring	Mulching
Grasses						
Echinochloa crusgalli	0.06	3.19	2.17	2.08	2.58	1.16
Commelina benghalensis	0.00	0.06	0.00	0.00	0.00	0.00
Total	0.06	3.25	2.17	2.08	2.58	1.16
Broad leaved						
Digera arvensis	0.00	0.08	0.25	0.17	0.00	0.19
Trianthema monogyna	0.08	0.12	0.08	0.00	0.00	0.12
Chenopodium album	0.00	0.25	0.06	0.00	0.08	0.06
Phyllanthus niruri	0.00	0.00	0.08	0.00	0.06	0.06
Total	0.08	0.45	0.47	0.17	0.14	0.43
Sedges						
Cyperus rotundus	0.06	0.19	0.25	0.12	0.33	1.17
Total	0.20	3.89	2.89	2.37	3.05	2.76

membrane structure and protein metabolism. As a result, soil solarization reduces the number of weed seedling and weed biomass of heat sensitive species. Sundari and Kalaisuderson (2005) also reported off-season soil solarization effective in reducing the infestation of all the dominant weed species in irrigated cotton soil. In view of growing concern for environmental safety and sustainability of agricultural production, integration of solarization practices would provide an eco-friendly and sustainable system.

SUMMARY

An experiment on evaluation of soil solarization on weed seed bank of soil was conducted in 2004 at College of Agriculture, Gwalior, in randomized block design with six non chemical agronomical weed management practices *viz.,* solarized (45 days) non-solarized, stale seed bed, deep ploughing, green manuring and mulching by green biomass. The soil temperature recorded under solarized conditions were 43.9^{0}C and 43.8^{0}C at 10 and 15 cm depth and it was 4.6^{0}C and 4.5^{0}C higher than non-solarized soil respectively. In solarized soil total number of grassy, broad leaved and sedges weeds waslowest, while highest grasses were reported in non-solarised soil. Total number of weeds was highest in non solarized soil followed by green manuring, stale seed bed, mulching, deep ploughing and non-solarised soil. Thus soil solarization was found to be the best non chemical agronomical practice for weed management methods used resulting to lowest weed seed bank.

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Short communication

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Efficacy of weed management practices in ratoon sugarcane

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Reduction in cane yield due to weeds occurs up to 40-67% (Chauhan and Srivastava 2002). Weed in sugarcane need to be controlled at formative stage. Weed control in sugarcane can be achieved by mechanical, chemical, chemical + mechanical methods and trash mulching (Singh *et al.* 1996). Sugarcane ratoon occupies majority of the area in Maharashtra. Economical weed management in sugarcane ratoon is essential for sustainable cane yield. Manual hoeing and weeding are costly and labour intensive. Thus, there is need to identify effective herbicides and also to integrate various methods of weed control for effective and economical weed management. Sugarcane being a highly fertilized crop requires frequent irrigations. Weeds grow vigorously and compete with the crop at tillering stage. Present study was undertaken to study the influence of weed management practices in controlling weeds and economics of various treatments in ratoon sugarcane.

A field experiment was conducted during 2006-09 at Central Sugarcane Research station, Padegaon. Ten treatments, *viz., c*ontrol (no hoeing, weeding and no herbicide application); three hoeings (1, 4 and 7 week after ratoon initiation); atrazine 2.0 kg/ha pre-emergence (PE) + 2,4 D 1.0 kg/ha at 45 days after ratoon initiation (DARI); atrazine 2.0 kg/ha PE + one hoeing at 45 DARI; metribuzin 1.0 kg/ha PE + 2.4-D 1.0 kg/ha at 45 DARI; metribuzin 1.0 kg/ha PE + one hoeing at 45 DARI; glyphosate 0.4 kg/ha at 3 weeks stage as directed spray + 2,4-D 1 kg/ha at 60 DARI; glyphosate 0.4 kg/ha at 3 weeks stage as directed spray + one hoeing at 60 DARI; trash mulching in alternate rows + hoeings at 1 and 6 week after ratoon initiation; trash mulching between all rows with recommended practice were replicated 3 times in a randomized block design. Ratoon of sugarcane variety '*Co 86032*' was cultivated during 2006-07, 2007-08 and 2008-09. Recommended dose of fertilizer *i.e.* 250 kg N + 115 kg P + 115 kg K/ha was applied, along with other package of practices. Soil was neutral (pH 7.6) and clay loam in texture. Data were analyzed and economics was calculated by considering the cost of cultivation, net returns and benefit: cost ratio.

Major weeds observed in the experimental plot were: *Cyperus rotundus, Cynadon dactylon, Parthenium hysterophours, Commalina benghalensis, Echinochloa* sp, *Virudus* sp, *Acalypha India, Convolvulus arvensis, Euphorbia hyperccifolia, Panicum isachmi* and *Digitaria sanguinalis*. The pooled data revealed that at 30, 60, 90 and 120 days after ratoon initiation, application of trash mulching between all rows with recommended practice recorded maximum weed control efficiency, followed by trash mulching in alternate rows + hoeings at 1 and 6 week after ratoon initiation (Table 1).

The highest cane yield (98.0 t/ha) and CCS yield (15.5 t/ha) were recorded with trash mulching between all rows with recommended practice. However, the cane yield obtained with trash mulching in alternate rows + hoeings at 1 and 6 week after ratoon initiation (95.3 t/ha) and three hoeings at 1, 4 and 7 week after ratoon initiation (94.0 t/ha) were at par with trash mulching between all rows with recommended practice. The minimum cane yield (66.6 t/ha) was observed in weed infested control. Similar results were reported by Chauhan and Srivastava (2002) in plant crop and Singh *et al.* (1995) in ratoon crop.

Gross monetary returns (₹ 1,07,831/ha) and net monetary returns (₹ 69,719/ha) were higher with trash mulching between all rows with recommended practice for sugarcane ratoon. However, these were at par with trash mulching in alternate rows + hoeings at 1 and 6 week after ratoon initiation and three hoeing (1, 4 and 7 week after ratoon initiation). Trash mulching between all rows with recommended practice also recorded higher B: C ratio (2.83), followed by trash mulching in alternate rows + hoeings at 1 and 6 week after ratoon initiation (2.69) and three hoeings (2.60).

It was concluded that trash mulching between all rows with recommended practice for sugarcane ratoon recorded higher weed control efficiency as well as produced significantly higher cane yield and net profit.

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Table 1. Mean yield and economics of sugarcane ratoon as affected by various treatments (pooled data of 3 years)

Treatment	Cane yield (t/ha)	CCS yield (t/ha)	Weed control efficiency at 120 DAR (%)	Total monetary returns (x10^3 ₹/ha)	Net profit (x10^3 ₹/ha)	B:C ratio
Unweeded control	66.6	9.08	-	73.43	37.50	2.04
Three hoeings (1, 4 and 7 weeks after ratoon initiation)	94.0	13.51	44.6	103.44	63.61	2.60
Atrazine 2.0 kg/ha PE + 2,4 D 1.0 kg/ha at 45 days after ratoon initiation (DARI)	76.9	11.17	37.7	84.76	45.76	2.17
Atrazine 2.0 kg/ha PE + one hoeing at 45 DARI	82.9	11.45	39.1	91.31	51.87	2.31
Metribuzin 1.0 kg/ha PE + 2,4 D 1.0 kg/ha at 45 DARI	87.8	12.56	41.1	96.61	56.43	2.40
Metribuzin 1.0 kg/ha PE + one hoeing at 45 DARI	91.6	13.05	45.4	101.03	60.68	2.50
Glyphosate 0.4 kg/ha at 3 weeks stage as directed spray + 2,4 D 1 kg/ha at 60 DARI	81.7	11.52	40.0	89.93	52.41	2.40
Glyphosate 0.4 kg/ha at 3 weeks stage as directed spray + one hoeing at 60 DARI	79.2	11.07	36.1	87.83	49.41	2.29
Trash mulching in alternate rows + hoeings at 1 and 6 week after ratoon initiation	95.3	13.87	47.9	104.85	65.84	2.69
Trash mulching between all rows with recommended practice	98.0	15.50	54.6	107.83	69.72	2.83
LSD (P=0.05)	5.0	1.20	-	5.62	6.67	-

SUMMARY

A field experiment was conducted to evaluate relative performance of weed management practices in sugarcane ratoon during 2006-09 at Padegaon, Maharashtra. Trash mulching between all rows with recommended practice recorded significantly higher cane yield (98 t/ha), which was at par with trash mulching in alternate rows + hoeings at 1st and 6th week after ratoon initiation (95.3 t/ha) and three hoeings at 1, 4 and 7 weeks after ratoon initiation (94.0 t/ha). Highest net returns (69,719/ha) and B:C ratio (2.83) were observed due to trash mulching between all rows for sugarcane ratoon with recommended practice.

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Short communication

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Growth and productivity of wheat as influenced by weed management

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Key words : Herbicides, Growth, Yield attributes, Yield, Wheat

Wheat (*Triticum aestivum* L.) is the most important staple food crop of India. Wheat is the predominant *Rabi* season crop of north central and upper peninsular region of country. About 20-25% of the area under wheat is infested with narrow and broad leaf weeds, resulting in yield loss of 30-50% (Singh and Ghosh 1992). Shortage of labourers at right time to control weed by hand weeding has become difficult and uneconomical. Some herbicides like 2,4-D, isoproturon and new broad spectrum herbicides like metribuzin and sulfosulforon have great importance in controlling weeds very effectively. To test the efficacy of these herbicides alone and in combination, an experiment was planned.

Field experiment was conducted at Agronomy Farm, College of Agriculture, Pune during *Rabi* 2009-10. The experiment was laid out in randomized block design with three replications. The nine treatment consisted of weedy check (T_1), weed free check (T_2), hand weeding at 30 DAS (T_3), post-emergence application of isoproturon 1000 g/ha (T_4), sulfosulfuron 25 g/ha (T_5), 2,4-D 750 g/ha (T_6), metribuzin 175 g/ha (T_7), isoproturon 500 g + 2,4-D 375 g/ha (T_8) and sulfosulfuron 12.5 g/ + 2,4-D 375 g/ha (T_9) at 30 DAS. Wheat variety '*Trambak*' was sown 125 kg seed/ha at a row spacing of 22.5 cm. The soil of the experimental field was clayey loam in texture with low (163.42 kg/ha), medium (30.46 kg/ha) and high (468.00 kg/ha) in available NPK, respectively. The recommended dose NPK fertilizers *i.e*. 120 kg N, 60 kg P_2O_5 and 40 kg K_2O were applied. Post-emergence herbicides were applied at 30 DAS through Knapsack sprayer with flat fan type of nozzle using 500 litres of water/ha.

Differences in growth and yield attributes differed significantly due to weed control treatments (Table 1). The significantly higher plant height (79.6 cm) and leaf area index (4.03) were recorded in weed free check (T_2) than rest of the treatments; however, it was at par with application of sulfosulfuron 25 g/ha (T_5). The same treatment (T_2) also registered maximum and significantly higher number of tillers per plant (4.20) than all other treatments except application of sulfosulfuron 25 g/ha (T_5) and hand weeding at 30 DAS (T_3), where, it was found at par with each other. The weed free check also significantly out yielded for dry matter 20.36 g/plant. Amongst the herbicide treatments, application of sulfosulfuron 25 g/ha (T_5) being at par with metribuzin 175 g/ha (T_7), recorded statistically more dry matter per plant (18.16 g). However, significantly lower values of all growth attributes were registered with weed check. The more growth attributes in weed free check followed by sulfosulfuron 25 g/ha was might be due to lower weed competition for water, sunlight and greater availability of nutrients, which resulted profuse growth of plants and also effective control of both grassy and broadleaved weeds by sulfosulfuron. Wani *et al.* (2005) have also reported that spraying of sulfosulfuron 30 g/ha gave higher plant height and dry matter production which was at par with weed free treatments. These results are in agreement with those reported by Dawson *et al.* (2008) and Singh *et al.* (2009).

The yield attributes *viz.*, panicle length (8.16 cm), number of spikelet/panicle (17.36), grain weight (8.33 g) were maximum and significantly more under weed free check treatment (T_2) than rest of the treatments (Table 2). The same treatment (T_2) also noticed significantly higher number of grains per panicle and thousand grain weight, however, it was found at par with application of sulfosulfuron 25 g/ha (T_5) for number of grains per panicle and with hand weeding at 30 DAS (T_3) for thousand grain weight. Amongst the herbicides treatments, application of sulfosulfuron 25 g/ha showed its superiority over rest of the weed control treatments. However, minimum values of all yield attributes were registered with weedy check. These results are in conformity with the findings of Dawson *et al.* (2008) and Singh *et al.* (2009).

Productivity measured in terms of grain and straw yield differed significantly due to different weed control treatments (Table 2). The maximum and statistically higher grain and straw yield of 4.03 and 5.35 t/ha, respectively, were recorded with weed free check than rest of the treatments. The second best treatment was application of sulfosulfuron 25 g/ha, which showed its significant supe-

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Table 1. Growth parameters of wheat as influenced by different treatments

Treatment	Plant height (cm)	Number of tillers/plant	Leaf area index	Dry matter/plant (g)
T_1 –Weedy check	68.6	2.33	3.04	12.50
T_2 –Weed free check	79.6	4.20	4.03	20.36
T_3 – Hand weeding at 30 DAS	75.6	3.90	3.84	16.56
T_4– Post-emergence isoproturon 1000 g/ha at 30 DAS	73.3	3.06	3.36	14.68
T_5 – Post-emergence sulfosulfuron 25 g/ha at 30 DAS	77.6	4.03	3.92	18.16
T_6 – Post-emergence 2, 4-D 750 g/ha at 30 DAS	74.3	3.66	3.73	16.50
T_7 – Post-emergence metribuzin 175 g/ha at 30 DAS	75.3	3.80	3.81	16.90
T_8 – Post-emergence isoproturon 500 g/ + 2, 4-D 375 g/ha at 30 DAS	74.6	3.36	3.79	15.70
T_9 – Post-emergence sulfosulfuron 12.5 g/+ 2, 4-D 375 g/ha at 30 DAS	74.0	3.36	3.70	15.46
LSD (P=0.05)	2.13	0.35	0.18	1.45

Table 2. Yield attributes, grain and straw yield of wheat as influenced by different treatments

Treatment	Length of panicle (cm)	No. of spikelet/ panicle	No. of grains/ panicle	Grain weight /plant	1000 grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
T_1 – Weedy check	6.69	14.7	33.4	5.33	35.53	2.51	2.89
T_2 – Weed free check	8.16	17.4	41.6	8.33	41.50	4.03	5.35
T_3 – Hand weeding at 30 DAS	7.63	16.2	38.3	7.50	40.46	3.61	4.49
T_4– Post-emergence isoproturon 1000 g/ha at 30 DAS	7.16	15.3	35.5	6.16	37.33	3.16	3.71
T_5– Post-emergence sulfosulfuron 25 g/ha at 30 DAS	7.86	16.7	39.4	7.70	40.92	3.71	4.78
T_6 – Post-emergence 2, 4-D 750 g/ha at 30 DAS	7.43	16.1	37.4	7.30	38.80	3.42	4.31
T_7 – Post-emergence metribuzin 175 g/ha at 30 DAS	7.60	16.4	38.1	7.40	39.46	3.59	4.44
T_8 – Post-emergence isoproturon 500 g/ + 2, 4-D 375 g/ha at 30 DAS	7.46	16.0	37.6	7.03	38.50	3.38	4.24
T_9 – Post-emergence sulfosulfuron 12.5 g/+ 2, 4-D 375 g/ha at 30 DAS	7.30	15.5	36.8	6.80	38.13	3.32	3.88
LSD (P=0.05)	0.25	0.6	2.3	0.58	1.54	0.12	0.17

riority for grain (3.71 t/ha) and straw yield (4.78 t/ha) than rest of the treatments, whereas, grain yield was at par with treatment T_3 and T_7. The higher values of grain yield with these treatments may be ascribed to marked decrease weed population and weed dry weight and thereby better growth and increased the productive tillers and yield attributes. Singh *et al.* (2009) found that application of sulfosulfuron 25 g/ha have a significant impact on growth and yield attributes, which resulted higher grain yield of 3.53 t/ha and being at par with one hand weeding at 30 DAS.

The aforesaid results indicated that growing of wheat with application of sulfosulfuron 25 g/ha as post-emergence at 30 DAS showed better proposition for higher productivity.

SUMMARY

A field experiment was conducted during *Rabi* season of 2009-10 at College of Agriculture, Pune to study the eficacy of different herbicides on growth and productivity of wheat. The growth attributes of wheat crop in terms of plant height, number of tillers/plant, leaf area index, and dry matter accumulation/plant were maximum with weed free check. Among the herbicide treatments, post-emergence application of sulfosulfuron 25 g/ha recorded higher values of all these growth attributes characters and were on par with hand weeding at 30 DAS and application of metribuzin 175 g/ha. However, substantial reduction in growth characters was observed in weedy check. The values of yield attributes were higher in magnitude in weed free check treatment. The next best treatment was application of sulfosulfuron 25 g/ha. Amongst the weed control treatments, application of sulfosulfuron 25 g/ha, recorded maximum grain and straw yield of 3.71 and 4.78 t/ha, respectively, as compared to other treatments. However, substantial reduction in growth and yield attributes and yield were observed in weedy check.

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Short communication

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Effect of weed management practices on seed yield and nutrient uptake in sesame

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India is the world's largest producer of sesame accounting nearly 35% of the total production but its productivity is extremely low (368 kg/ha). Weed management appears to be one of the major constraints for such low productivity. Weed competes with crop plants for resources *i.e.* water, light, space and nutrients *etc.* causing reduction in yield and economic return. Sesame being a rainy season and slow growing crop during early stage, provide ample opportunities for weed infestation. NPK efficiency may also be improved by adopting suitable weed management practices. Chemical weed control is time saving, easier, economical and can be adopted timely, particularly where scarcity of agricultural labours exists during important field operations as compared to manual weeding (Brar and Mehra 1989). As the information on these aspects is lacking under the semi arid conditions of northern M.P., a study was carried out on sesame crop to find out most suitable and economical method of weed control for higher production and economic returns.

Field study was carried out during rainy season of 2010 at RVSKVV College of Agriculture, Gwalior. The soil of the experimental field was sandy loam and slightly alkaline (7.97 pH) with 237 kg/ha available N, 23.73 kg/ha P, and 477.22 kg/ha K. Ten treatments comprising trifluralin, pendimethalin each at 0.75 kg/ha, quizalofop 0.05 kg/ha, clodinafop 0.06 kg/ha, integration of each of these herbicides with 1 HW at 30 days after sowing (DAS), weedy check and two hand weeding at 15 and 30 DAS were replicated three times in randomized block design (Table 1).

Sesame variety '*JT-S-8*' was sown at 30 cm row spacing on 29th July, 2010 and harvested on 21st October, 2010. Crop was raised as per recommended package of practices except weed control treatments. Trifluralin was incorporated in 2-3 cm top soil before sowing, pendimethalin was sprayed after sowing, while quizalofop-ethyl and clodinafop were sprayed at 20 DAS. All the herbicides were applied with manually operated knapsack sprayer fitted with flat fan nozzle at spray volume of 600 l/ha. Weed density and dry weight were recorded at 60 DAS with the help of 1x1m quadrate by throwing randomly at three place from each plot. NPK content in seed and stalk of soybean and weeds (60 DAS) were determined by using alkaline permangnate, colometrically by Olsen and Flame photometer methods, respectively (Dubey and Arora 2010). The nutrient uptake by seed, stalk and weeds were computed by multiplying the per cent NPK content in plants with their respective dry weight. The economics was calculated on the basis of prevailing market rates of agriculture produce and cost of cultivation treatment wise.

Experimental field was infested with *Digera arvensis* (33.67%) *Echinochloa crusgalli* (21.76%), *Cyperus rotundus* (17.6%), *Commelina bengalensis* (17.34%) and *Phyllanthus niruri* (9.91%). All the weed control treatments played a significant role in reducing weed population and weed dry weight as compared to weedy check at 60 DAS. The maximum weed count and weed dry weight was observed in weedy check plots, whereas the minimum was recorded in 2 hand weeding (15 and 30 DAS) (Table 1). Among the herbicidal treatments, trifluralin at 0.75 kg/ha supplemented with one hand weeding recorded lowest weed population and weed dry weight followed by quzalofop-ethyl 50 g/ha + 1 hand weeding. All the herbicides when combined with one hand weeding at 30 DAS had pronounced effect on weeds as compared to their alone application.

Highest seed and stalk yield (1190 and 4861 kg/ha) of sesame was obtained by two hand weeding at 15 and 30 DAS which was found at par with trifluralin supplemented with one hand weeding, while weedy check yielded lowest seed (451 kg/ha). Integration of trifluralin, pendimethalin, quizalofop and clodinafop with one hand weeding at 30 DAS gave significantly higher seed yield than herbicide application alone. Trifluralin at 0.75 kg/ha supplemented with one hand weeding produced higher seed yield of 1127 kg/ha which was significantly higher by 250% over weedy check and was closely followed by quizalofop 0.05 kg/ha supplemented with one hand weed-

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Table 1. Effect of various weed control treatments on total weed population, weed dry matter, yield, and net income of sesame

Treatment	Total weed population/ m^2	Weed biomass (g/m^2)	Seed yield (kg/ha)	Stalk yield (kg/ha)	Net income (₹/ha)	B:C Ratio
Trifluralin 0.75 kg/ha (PPI)	13.0	72.5	799	4157	27,667	3.73
Pendimethalin 0.75 kg/ha (PE)	18.0	95.0	716	3917	23,349	3.21
Quizalofop-ethyl 50 g/ha PoE at 20 DAS	14.7	78.7	743	4028	24,292	3.22
Clodinofop 60 g/ha PoE	25.1	125.8	639	3856	19,979	2.92
Trifluralin 0.75 kg/ha PPI + one HW 30 DAS	6.2	32.5	1127	4727	41,357	4.55
Pendimethalin 0.75 kg/ha PE + one HW 30 DAS	9.1	48.0	979	4393	34,061	3.82
Quizalofop-ethyl 50 g/ha PoE (20 DAS) + one HW 30 DAS	8.7	40.2	1057	4523	37,334	4.00
Clodinofop 60 g/ha PoE + one HW at 30 DAS	12.6	65.5	820	4250	26,883	3.26
2 HW at 15 and 30 DAS	3.3	18.0	1190	4861	42,391	4.12
Weedy check	78.0	300.0	451	3481	12,527	2.38
LSD (P=0.05)	4.36	8.62	88	359	-	-

PPI- Pre-plant incorported; PE- Pre-emergence

Table 2. Effect of weed management practices on NPK uptake by weeds, seed and stalk of sesame

Treatment	Weeds (kg/ha)			Seed (kg/ha)			Stover (kg/ha)			Total plant (kg/ha)		
	N	P	K	N	P	K	N	P	K	N	P	K
Trifluralin 0.75 kg/ha (PPI)	12.0	1.7	9.1	23.5	5.6	2.5	22.9	10.8	47.1	46.4	16.5	49.6
Pendimethalin 0.75 kg/ha (PE)	15.4	2.3	11.8	21.2	5.2	2.4	22.3	10.6	45.0	43.5	15.7	47.4
Quizalofop-ethyl 50 g/ha PoE at 20 DAS	12.9	1.9	9.8	21.9	5.3	2.4	22.9	10.5	45.9	44.9	15.7	48.3
Clodinofop 60 g/ha PoE	19.8	2.9	15.3	19.0	4.7	2.2	22.4	10.8	44.7	41.4	15.5	46.9
Trifluralin 0.75 kg/ha PPI + one HW 30 DAS	5.4	0.8	4.6	32.8	7.7	3.1	24.6	10.4	51.5	57.4	18.1	54.7
Pendimethalin 0.75 kg/ha PE + one HW 30 DAS	8.0	1.2	6.4	28.6	6.8	2.6	23.3	10.5	48.8	51.9	17.3	51.4
Quizalofop-ethyl 50 g/ha PoE (20 DAS) + one HW 30 DAS	6.7	0.9	5.5	30.8	7.2	2.9	23.9	9.9	49.7	54.7	17.1	52.7
Clodinofop 60 g/ha PoE + one H.W. at 30 DAS	10.7	1.6	8.2	24.1	5.8	2.5	23.4	11.0	48.0	47.5	16.9	50.6
2 HW at 15 and 30 DAS	3.1	0.4	2.6	34.6	8.1	3.3	25.3	10.7	52.5	59.9	18.8	55.8
Weedy check	45.0	6.9	36.0	13.5	3.4	1.6	20.9	10.4	41.8	34.4	13.8	43.3
LSD (P=0.05)	0.31	0.04	0.25	2.59	0.62	0.27	1.95	NS	NS	3.04	1.02	4.00

ing (1057 kg/ha). This may be attributed to less competitive interaction between crop and weed plants due to lower weed count and weed dry weight.

Significantly higher NPK uptake was noted in all the herbicidal and manual weeded treatments as compared to weedy check. The highest NPK uptake (59.91 kg N, 18.79 kg P and 55.83 kg K) was recorded in two hand weeding at 15 and 30 DAS which was found at par with trifluralin 0.75 kg/ha supplemented with one hand weeding at 30 DAS and significantly superior to those recorded in rest of treatments (Table 2). Increase in productivity and nutrient content in sesame was responsible for higher nutrients uptake by soybean showing less weed population and dry weight.

Significantly lower NPK depletion were observed in all herbicidal and manually weeded plots as compare to weedy check. Among all weed control measures, the least NPK was removed by weeds in 2 HW at 15 and 30 DAS treatment and this was found significantly superior to all other treatments (Table-2). Heavy weed infestation in weedy check removed 45.0 kg nitrogen, 6.9 kg phosphorus and 36.0 kg potassium/ha whereas in hand weeding twice the weeds removed only 3.1 kg N, 0.5 kg P and 2.6 kg K/ha. Similar findings were reported for nitrogen uptake in sesame (Singh *et al*. 2001) and for NPK uptake in sunflower (Kumar *et al*. 2007 and Sumathi *et al*. 2009). Among herbicidal treatments, trifluralin 0.75 kg/ha supplemented with one hand weeding removed lowest NPK followed by quizalofop + one hand weeding.

SUMMARY

A field experiment was carried out at Gwalior during *Kharif* season of 2010 to access the effect of weed management practices to sesame on seed yield and nutrient uptake by crop and weeds and net returns. Two hand weeding at 15 and 30 DAS registered highest yield (1190.22 kg/ha) and net return (₹ 42391/ha) in addition to higher NPK uptake by crop and lower NPK uptake by weed. Among herbicidal treatments application of trifluralin 0.75 kg/ha followed by one hand weeding at 30 DAS was found superior for yield, NPK uptake by plant and net return. Integration of herbicides *viz.,* trifluralin, pendimethalin, quizalofop ethyl and clodinafop with one hand weeding at 30 DAS was found more effective as compared to their alone use. NPK removed by weeds was heighest in weedy check and lowest in two hand weeding followed by trifluralin 0.75 kg/ha integrated with one hand weeding at 30 DAS.

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Short communication

Indian Journal of Weed Science **44**(2): 132–134, 2012

Rotary weeder for drudgery reduction of women during weeding in rice field

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Key words: Drudgery reduction, Farm women, Weeding tools

With the advancement of agriculture, farm women are being encouraged to use weeding tools like cono weeder, rotary weeder and peg type dry land weeder *etc*, instead of hand weeding. Evaluation of the performance of rotary weeder for drudgery reduction of farm women (FW) is inevitable as weed infestation is one of the limiting factors in the paddy cultivation. The weeding operation is mainly done by women in the paddy and vegetable field in want of availability of men labour. Agarwal (2007) advocated technology model for use by the women. It is expected that role of women will increase in field operation in agriculture (Das). Rotary weeder acts by uprooting and burying of weeds in between standing rows of paddy crop in wet lands. It disturbs the top soil and increases aeration also. The equipment is operated in standing posture thus avoids bending involved during uprooting of weeds by hands in traditional practice. The objectives of the study was to evaluate rotary weeder and hand weeding in terms of its ergonomic effectiveness such as - Energy requirement, Subjective judgement of Work Related Body Discomfort (WRBD), Work performance in comparison with hand weeding for drudgery reduction of Farm Women during paddy weeding.

The study was carried out on 10 farm women of the age group of 25-45 years which were involved in paddy weeding activity. The field experiment was conducted in the month of July to September. Mean age of the respondents engaged in weeding was 30 years, body height 156.5 cm and body weight as 46.5 kg. Stopwatch was used to measure the time required and a meter tape was used to measure the area covered. Assessment of physiological stress was done by recording of using a Digital Heart Rate Monitor. In the morning, resting heart rate (RHR) of the respondent was recorded and after completion of the activity, working heart rate (WHR) was recorded. From the average values of heart rate, energy expenditure was calculated with the help of formulae given by Varghese *et al*. (1994) which is as follows:

1. Energy expenditure rate (EER) and cardiac cost
   EER (k_j/min) = 0.159×HR (beats/min) - 8.72

where, EER = Energy expenditure rate (k_j/min), HR = Heart rate (beats/min)

From the values of change in heart rate (beats/min) and output (m^2/hr), the cardiac cost was calculated. The experiments were conducted during *Kharif* seasons of two consecutive years in 2010 to 2011 at farmers field.

The heart rate, cardiac cost and energy expenditure rate of 10 women are given alngwith mean values (Table 1).

Values of HR were 40.8 and 19.8 beats/min for hand weeding and rotary weeder, respectively (Table 2). The cardiac cost (beats/m^2) was 39.62 and 22.29, respectively for hand weeding and rotary weeder. The Energy expen-

Table 1. Heart rate (HR), cardiac cost (CC) and energy expenditure rate (EER)

FW	HR (beats/min)		Cardiac cost (beat/m^2) of area harvested		Energy expenditure rate (K_j/min)	
	Hand weeding	Rotary weeder	Hand weeding	Rotary weeder	Hand weeding	Rotary weeder
S1	31	18	35.4	17.1	11.0	15.9
S2	49	22	46.0	26.8	10.8	15.8
S3	42	23	44.2	22.2	10.5	16.1
S4	40	23	43.4	21.3	10.6	16.1
S5	39	19	39.6	22.5	10.6	15.9
S6	19	39	39.6	23.2	12.1	16.1
S7	12	42	25.0	21.2	10.6	15.9
S8	24	44	51.1	24.4	10.8	16.1
S9	16	49	33.3	26.2	11.6	16.1
S10	22	33	38.6	18.0	11.6	15.9
Mean value	20	41	39.6	22.30	11.04	15.99

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Table 2. Heart rate response and output during weeding

Farm women	Heart rate (beats/min)		Output (m^2/hr)	
	Hand weeding	Rotary weeder	Hand weeding	Rotary weeder
S1	121	155	29	112
S2	123	154	30	110
S3	125	156	31	111
S4	122	156	32	113
S5	122	155	29	104
S6	131	156	29	112
S7	122	155	29	110
S8	123	156	28	111
S9	128	155	29	113
S10	128	156	34	104
Mean value	124	155	30	110

diture rate was 11.04 and 15.99k_j/min for hand weeding and rotary weeder, respectively (Fig.1). The mean output of farm women was 30 and 110 (m^2/hr) for hand weeding and rotary weeder, respectively (Fig. 2).

Table 2 shows Heart Rate (HR) of the FW during weeding ranged between 121 to 131 beats/min for hand weeding and 154 to 156 for rotary weeder. The mean of HR during hand weeding and rotary weederwas 124.5 and 155.4, respectively. The mean values of area covered by hand weeding and rotary weeder was 30 and 110 m^2/hr respectively. Ergonomic results showed that the energy requirements for FW were 16.0 and 11.04 kJ/min in rotary weederand hand weeding respectively. The area covered by the rotary weeder was 110 m^2/hr as compare to 30 m^2/hr by hand weeding (nearly 4 times). The Overall Rated Perceived Exertion (ORPE) was used to express WRBD. It was more in hand weeding due to continuous bending posture as against standing posture.

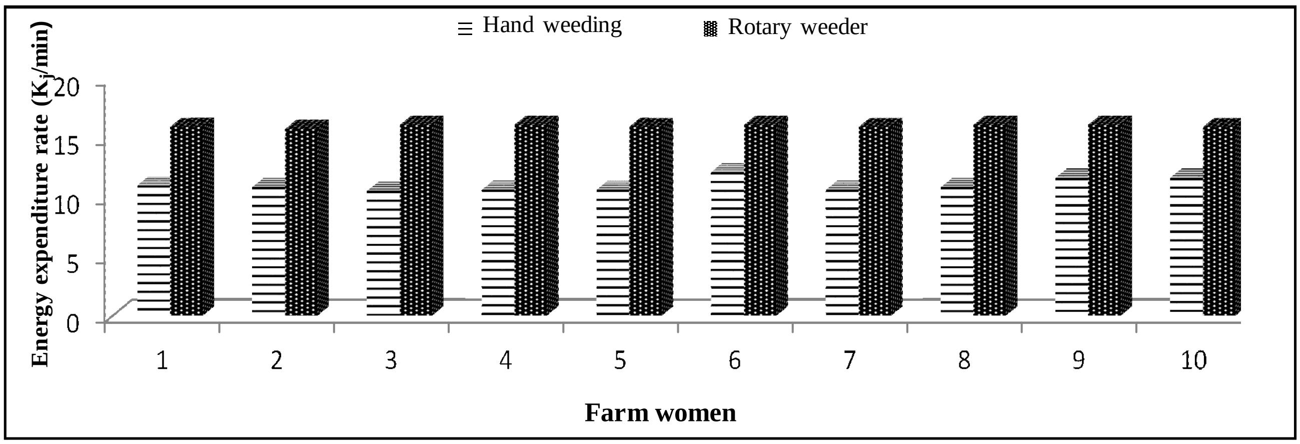

Fig. 1. Trend of energy expenditure rate (K_j/min)

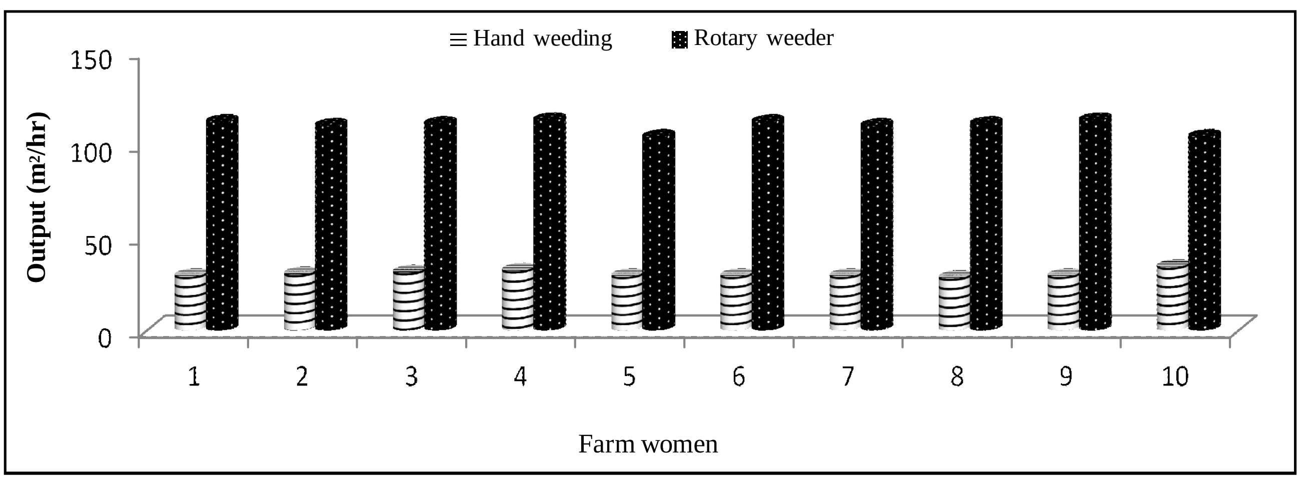

Fig. 2. Trend of output (m^2/hr)

SUMMARY

The study was conducted in Sinduri village of Shahdol district in Madhya Pradesh to evaluate rotary weeder's ergonomic effectiveness in terms of energy requirement, subjective judgement of Work Related Body Discomfort (WRBD) and work performance in comparison with hand weeding. Ergonomic results showed that the energy requirements for farm women were 16.0 and 11.04 k_j/min for rotary weeder and hand weeding, respectively. The area covered by rotary weeder was 110 m^2/hr as compare to 30m^2/hr by hand weeding (nearly 4 times). The Overall Rated Perceived Exertion (ORPE) was used to express WRBD. It was more in hand weeding due to continuous bending posture as against standing posture.

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Short communication

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Efficacy of imazethapyr on productivity of soybean and its residual effect on succeeding crops

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Key words: Growth, Imazethapyr, Residual effect, Soybean, Weed control, Yield

The existing herbicides recommended for weed control in soybean have shorter persistence and relatively narrow spectrum of weed control The herbicide imazethapyr is known to be very effective in controlling broad range of weeds including annual and perennial grasses for soybean and other legume crops (Patel *et al.* 2009). Imazethapyr has been extensively applied because of their high herbicidal activity at low application rates and broad spectrum of weed control. The present investigation aims to find the efficacy of imazethapyr in soybean and its residual effect on the succeeding sunflower and pearl millet followed by soybean.

Experiment was conducted in Agricultural Research Station, Bhavanisagar, Tamil Nadu Agricultural University, Coimbatore during 2009-10. The soil of the experimental field was red sandy loam having pH 6.72, EC 0.18 dS/m, OC 0.55%, available N, P, K 230, 20, 268 kg/ha, respectively. The treatments were applied consisting of imazethapyr 50, 75, 100 and 200 g/ha as early post-emergence (EPOE) at 15 days after sowing, oxyfluorfen 125 g/ha and pendimethalin 750 g/ha as pre-emergence (PE) at 3 days after sowing, hand weeding twice and control. All these treatments for comparison, except unweeded check were given with an earthingup on 45 DAS in randomized block design with three replications. Soybean variety *'CO (Soy) 3'* was sown in 30 cm wide rows. Crop phytotoxicity was studied three days after spraying of herbicide using standard method for post-emergence herbicide. Weed control efficiency (WCE) was calculated in relation to total biomass by using the following formula:

$$\text{WCI} = \frac{(X-Y)}{X} \times 100$$

Where,

X= biomass of weeds in weedy plots Y= biomass of weeds in treated plots and expressed in per cent.

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After the harvest of soybean, residual effect of treatments was studied by raising succeeding crops such as sunflower and pearl millet without disturbing the layout. The residual effect of treatments was assessed by recording the germination, plant height, dry matter production and yield of the succeeding crops.

The experimental field was infested with various weed species, consisting of dicot, monocot weeds and sedges. Most common weeds among grasses were *Dactyloctenium aegyptium, Acrachne racemosa, Bracharia reptans* and *Boerhaavia diffusa;* among broadleaved weeds *Digera arvensis, Parthenium hysterophorous* and *Trichodesma indicum* and *Cyperus rotundus* was the only sedge weed.

Effect on soybean

Plant height was altered due to application of different herbicides compared to unweeded control. At 30 and 45 DAS**,** application of EPOE imazethapyr at 100 g/ha registered taller plants followed by EPOE imazethapyr at 200 g/ha. Whereas, application of EPOE imazethapyr at 200 g/ha caused injury to soybean resulting in lesser plant height during initial stages which recovered at later growth stages (Table 1) by one or two irrigation. Unweeded control resulted in shorter plants, obviously due to the effect of weeds. Similarly, Lakshmanakumar (2008) observed that in tobacco post emergence application of imazethapyr increased the plant height significantly. Thus, heavy weed infestation resulted in etiolated soybean plants competeting for light. Minimum leaf are a index (LAI) was recorded in unweeded control. Higher LAI was recorded with EPOE imazethapyr at 100 g/ha (T_3) which was closely followed by EPOE imazethapyr at 200 g/ha and PE pendimethalin at 750 g/ha (Table 1). Whereas, all other treatments recorded lower LAI. It might be due to heavy weed infestation, which reduced aeration, light, nutrients, water, and space available to the soybean plants resulting in poor developments of leaf.

Weed control treatments positively influenced the dry matter production of soybean at different growth stages.

At 30 DAS, EPOE imazethapyr at 100 g/ha recorded higher dry matter of soybean (Table 1). At subsequent stages, treatments with EPOE imazethapyr either at 100 g/ha (T_3) or EPOE imazethapyr 200 g/ha (T_3) recorded higher DMP in all the stages from 30 DAS onwards. The reason might be due to the better weed control resulted in favourable environment to have higher nutrient uptake reflected on higher leaf area index and better source sink relationship for accumulating higher dry matter. Raghuwanshi (2005) had recorded higher biomass of sobean with imazethapyr application. On the other hand, unweeded control recorded lower total dry matter due to severe weed competition at all the stages of crop growth.

Crop phytotoxicity

The phytotoxic effect of imazethapyr was observed at higher doses *viz.*, 200 g/ha (T_4). However, EPOE imazethapyr at 200 g/ha recorded slight crop damage (rating = 30) at 3 days after herbicide spray (DAHS). At 7 DAHS, the effect was less (rating = 20) while after 14 DAHS, the effect was negligible (rating = 10) and at 21 DAHS the soybean plants recovered from phytotoxicity and the symptoms were not evident afterwards by one or two irrigation.

Effect on weeds

At 30 DAS, all the weed control treatments recorded more than 70% WCE, EPOE application of imazethapyr at 200 g/ha recorded higher WCE followed by application of imazethapyr at 100 g/ha (Table 1). More reduction of weed dry weight by reducing the weed density in these treatments might have resulted in higher WCE. At 45 and 60 DAS, same trend was observed with EPOE imazethapyr at 200 g/ha recording higher WCE followed by EPOE imazethapyr at 100 g/ha. Vyas and Jain (2003) also reported higher WCE after application of post-emergence application of imazethapyr.

Yield and yield attributes

Favourable crop growth environment with a minimum disturbance due to biotic factors like lesser weed competition reflected on crop yield by enhancing the growth and yield attributes. Among the weed control treatments, application of EPOE imazethapyr at 100 g/ha recorded higher grain yield (1645 kg/ha) which was on par with EPOE imazethapyr 200 g/ha. Similar results were reported by Chandel and Saxena (2001), where POE imazethapyr at 100 g/ha was as found to be effective in controlling weeds at various stages and also enhanced the grain yield to the tune of 51% over control in soybean. More number of pods and higher test weight were obtained with EPOE application of imazethapyr at 100 g/ha (T_3). It might be due to better control of weeds from earlier stage itself, followed by EPOE application of imazethapyr at 200 g/ha recorded higher yield attributes against unweeded control which obviously experienced severe weed competition at all crop growth stages. Similarly Singh and Mehar-Singh (2000) reported that due to better weed control resulted into higher number of pods, number of seeds per pod and bolder seeds were obtained (Table 2).

Germination percentage of the sunflower and pearlmillet had no significant difference among treatments. There was no residual toxicity on the succeeding crops. Plant height, dry matter production at 30 DAS showed no

Table 1. Effect of treatments on growth attributes and weed control efficiency

Treatment	Plant height (cm)		Leaf area index		Dry matter production (kg/ha)		Weed control efficiency (%)		
	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS	60 DAS
EPOE imazethapyr 50 g/ha	36.3	69.0	0.61	1.73	611	1385	77.7	59.7	93.1
EPOE imazethapyr 75 g/ha	37.6	70.0	0.63	1.85	633	1413	81.6	60.6	94.8
EPOE imazethapyr 100 g/ha	41.7	77.5	0.76	1.98	763	1655	87.7	71.9	96.8
EPOE imazethapyr 200 g/ha	39.1	76.6	0.70	2.20	717	1529	91.1	78.3	98.1
PE oxyfluorfen 125 g/ha	35.2	63.7	0.60	1.71	648	1253	80.0	55.5	93.8
PE pendimethalin 750 g/ha	36.1	68.5	0.61	1.79	632	1328	80.3	65.8	94.4
HW on 25 and 45 DAS	35.1	66.1	0.60	1.48	564	1055	81.4	50.9	53.5
Unweeded control	28.2	56.4	0.56	1.25	420	887	-	-	-
LSD (P=0.05)	2.8	6.9	0.08	0.62	70	222	NA	NA	NA

EPOE- Early post-emergence, PE- Pre-emergence, NA- Not analysed

Table 2. Effect of treatments on yield attributes and yield of soybean

Treatment	No. of pods per plant	No. of seeds per pod	100 seed weight (g)	Seed yield (kg/ha)
EPOE imazethapyr 50 g/ha	73.3	2.2	10.3	1387
EPOE imazethapyr 75 g/ha	86.5	2.3	10.8	1467
EPOE imazethapyr 100 g/ha	90.5	2.4	11.5	1645
EPOE imazethapyr 200 g/ha	89.3	2.4	11.1	1514
PE oxyfluorfen 125 g/ha	63.0	2.2	10.2	1304
PE pendimethalin 750 g/ha	83.3	2.1	10.9	1481
HW on 25 and 45 DAS	61.0	2.2	9.8	1234
Unweeded control	37.0	2.0	8.0	833
LSD (P=0.05)	13.2	NS	0.57	86

EPOE- Early post-emergence, PE- Pre-emergence, NA- Not analysed

Table 3. Residual effect of treatments on germination, growth characters and yield of succeeding crops

Treatment	Germination at 10 DAS (%)		Plant height at 30 DAS (cm)		Dry matter production at 30 DAS (kg/ha)		Seed yield (kg/ha)	
	Sunflower	Pearl millet	Sunflower	Pearl millet	Sunflower	Pearl millet	Sunflower	Pearl millet
T_1 - EPOE imazethapyr 50 g/ha	90.00	86.33	56.8	75.39	202	225	911	622
T_2 - EPOE imazethapyr 75 g/ha	90.23	89.00	59.3	75.77	222	218.	933	748
T_3 - EPOE imazethapyr 100 g/ha	91.00	89.33	63.5	77.20	227	227	947	633
T_4 - EPOE imazethapyr 200 g/ha	90.73	88.67	63.2	78.28	242	242	1003	781
T_5 - PE oxyfluorfen 125 g/ha	87.00	86.00	53.9	72.18	219	230	911	777
T_6 - PE pendimethalin 750 g/ha	89.00	85.00	53.6	72.47	204	219	755	688
T_7 - HW on 25 and 45 DAS	90.67	87.67	57.3	70.71	211	133	844	803
T_8 - Unweeded control	90.66	86.67	58.3	69.27	222	121	800	788
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

EPOE- Early post-emergence, PE- Pre-emergence, NA- Not analysed

distinct variation in the test crops due to different dose of imazethapyr (Table 3). Various dose of imazethapyr tested in soybean had no adverse residual effect on the growth of the succeeding crop. Yield of sunflower and pearl-millet showed no distinct variation in succeeding crop due to different dose of imazethapyr (Table 3). Rana and Angiras (1997) also observed that residues of imazethapyr at 200 g/ha decreased significantly due to weed dry matter accumulation and had no effect on succeeding crop of wheat and pea. Thus, herbicidal weed control using early post-emergence imazethapyr at 100 g/ha followed by earthing up on 45 DAS was the best treatment to control majority of weeds for obtaining higher productivity of soybean and has no residual effect on succeeding crops.

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SUMMARY

Field experiment was conducted to evaluate the efficacy of imazethapyr on weed control in soybean and its residual effect on succeeding crops. Early post-emergence application of imazethapyr reduced broad-leaved weeds and grass density as well as dry weight when compared with pre-emergence application of pendimethalin and oxyfluorfen. Imazethapyr at 200 g/ha decreased the dry weight accumulation of all weeds significantly followed by imazethapyr 100 g/ha. Due to phytotoxic effect at 200 g/ha during initial stages yield and yield attributes were get reduced. Imazethapyr at 100 g/ha was found best treatment by giving more seed yield. To study the residual effect of imazethapyr on succeeding crops, sunflower and pearl millet were grown without disturbing the soil. The residues of imazethapyr at different doses did not influence germination, growth, yield of sunflower and pearl millet and was statistically at par with checks.

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Guidelines for Contributors

Indian Joumal of Weed Science is a quarterly journal publishing original research papers, short communications and review articles (invited or with prior approval of the title reflecting substantial contributions of the author) covering all areas of weed science research.

The papers submitted should not have been published or communicated elsewhere. Authors will be solely responsible for the factual accuracy of their contribution. Manuscript should not carry any material already published in the same or different forms.

The article should present a complete picture of the investigation made and should not be split into parts. However, in exceptional cases where a large volume of in-depth data are collected based on multi-season experimentation, the article can be split into two or three parts, with the same main title and a different sub-title in short. In such articles, proper continuity should be maintained in presentation of information, and all such articles should be submitted together at the same time.

Format

Full length article should be suitably divided into the following sub-sections; ABSTRACT, Key words, introduction, MATERIALS AND METHODS, RESULTS AND DISCUSSION and REFERENCES. The heading, introduction need not be mentioned in the text.

Title: The title of article should be informative but concise and should not contain abbreviations. It should indicate the content of the article essential for key word indexing and information retrieval. It should be set in small and bold letters. A good title briefly identifies the subject, indicates the purpose of study and introduces key terms and concepts. Title should not be started with the waste words like 'a study of', 'effect of', 'influence of' , 'some observations on', 'a note of' *etc.* The title should indicate preferably English name or most popular common name of the crops or organisms studied, wherever relevant. Scientific name can be given in abstract and introduction. Authority for such a name should be given at first mention in the text. A short title should be given for running headlines and should cover the main theme of the article.

Author(s) name(s) and affiliations: The name(s) of the author(s) should be given in small letters with sentence case separated by 'comma' or by 'and'. Institute name where the research was carried out should be given in italics. If authors are of different institutes, these can be mentioned by allotting number like 1, 2 or 3 as superscript over the name of author. The affiliation of such author may by given below of the corresponding author email address. Sometimes authors retire and change frequently and wish to give their current address, this should be given as foot note. Email address of main author or corresponding author should be given at the bottom.

Abstract: The abstract should contain at least one sentence on each of the following: objective of investigation (hypothesis, purpose, collection, result and conclusions). Give complete scientific name for plants or other organisms and full name of any symbol or abbreviations used. There is a need to mention place, name and priod of study in abstract. Emphasis should be given to highlight the results and the conclusion of the study. It should not exceed a total length of 200-250 words. Abstract should not have the words like 'will be explained or will be discussed'. Key words (5-6) should be given at the end of the abstract and should be arranged alphabetically. Each key word should be started with capital letter and separated by comma (,) from other words.

Introduction: Introduction should be brief and to the point, cover the problem and should justify the work or the hypothesis on which it is based. In introduction, a detail review is not necessary. However, to orient readers, important references about previous concepts and research should be given. It should briefly state the currently available information and should identify the research gap that is expected to be abridged through this investigation. Give preference to recent references from standard research publication unless it is of historical importance or a landmark in that field.

Materials and Methods: This part should begin with information relating to period/season/year and place of study, climate or weather conditions, soil type *etc.* Treatment details along with techniques and experimental design, replications, plot size *etc.* should be clearly indicated. Use of symbols for treatments may be avoided and an abbreviation should be fully explained at its first mention. Crop variety, methodology for application and common cultivation practices should be mentioned. Known methods may be just indicated giving reference but new techniques developed and followed should be described in detail. Methods can be divided into suitable sub-headings, typed in bold at first level and in italics at second level, if necessary.

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Acknowledgement: The authors may place on record the help and cooperation or any financial help received from any source, person or organization for this study. This should be very brief.

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Anonymous. 2006. Long-term herbicide trial in transplanted lowland rice-rice cropping system, pp 62-68. In: *Annual Progress Report,* AICRP on Weed Control, Tamil Nadu Agricultural University, Coimbatore.

DWSR. 2010. Annual Report, 2010-11, pp 35-37. Directorate of Weed Science Research, Jabalpur

Gopal B and Sharma KP. 1981. *Water hyacinth (Eichhornia crassipes) the most troublesome weeds of the world.* Hindasia Publisher, New Delhi, 129p

Sushilkumar, Sondhia S and Vishwakarma K. 2003. *Role of insects in suppression of problematic alligator weed (Altemanthera philoxeroides) and testing of herbicides for its integrated management.* Final Report of ICAR Adhoc Project, 39 p.

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