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Review/Overview

Effect of application of post-emergence herbicides at different levels of available soil moisture content in irrigated wheat (*Triticum aestivum*)

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) season of 2008–09 and 2009–10 at Jabalpur, Madhya Pradesh, to study the effect of post emergence herbicides (isoproturon @ 0.75 kg/ha, clodinafop @ 0.06 kg/ha and clodinafop followed by 2,4-D @ 0.5 kg/ha) against weeds under different available soil-moisture regimes (ASM) (100%, 95%, 90%, 85% and 80%) on weeds, nutrient depletion by weeds and uptake by crop and the grain yield and economics of wheat [*Triticum aestivum* (L.) emend. Fiori & Paol]. Herbicidal application at 100% available soil moisture resulted in significantly lowest weed density and total dry weight of weeds during both the years and hence lowered the nutrient depletion by weeds and increased the uptake by the crop. The presence of 100% available soil moisture registered significantly higher grain yield of wheat (6.1 t/ha) and proved significantly superior to 85 and 80% ASM. Post-emergence application of clodinafop followed by 2,4-D caused significantly lowest total weed density (7.8/m^2) and dry weight (5.1 g/m^2), which resulted in production of higher grain yield as well as net monetary returns over isoproturon, clodinafop and weedy check. Maximum benefit: cost ratio was obtained with 100% available soil moisture along with application of isoproturon.

Key words **:** Available soil moisture, Clodinafop, Crop protection, Isoproturon, Nutrient depletion, Wheat

Wheat is one of the most important cereal crops, occupying the prime position among food crops in the world. In India, it is the second important food crop being next to the rice. With the introduction of high-yielding dwarf varieties coupled with increased use of fertilizer and irrigation, the weed problems have increased tremendously. Slow growth of wheat plant at early stage and application of more fertilizer as well as irrigation right from sowing encourages the rapid growth of weeds, making the cultivation of wheat more problematic and if weeds are not controlled in time, they cause substantial loss in yields to the tune of 15–40% (Jat *et al.*, 2003). Removal of weeds through hand weeding is an age-old practice but due to high labour wages coupled with non-availability at the right time, herbicidal weed control remains only the alternative practice for economical weed management in wheat crop. Many herbicides are being used for effective control of weeds in this crop but their weed-control efficacy is affected to great extent due to variation in moisture content in the soil at the time of application of herbicides whether applied as pre-emergence or post-emergence (Anderson, 1983). Presently, isoproturon and clodinafop are the most widely used herbicides in wheat for effective control of weeds but sometimes they have not been found very effective due to lack of proper moisture at the time of application. Moisture and herbicide may interact each other in reducing dry-matter production of weeds and increasing the grain yield of wheat. An appropriate adjustment of time of herbicide application in relation to suitable soil moisture seems desirable for proper activity of herbicides. As the soil moisture decreases, the weeds are not controlled due to lower herbicidal absorption and poor physiological activity (Porwal and Dadheech, 2008). Hence, the present experiment was carried out with the objective to assess the effect of available soil-moisture content and different weed-control treatments on growth and yield of wheat.

MATERIALS AND METHODS

A field experiment was conducted at Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur, Madhya Pradesh, during winter (*rabi*) season of 2008–09 and 2009–10. The

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topography of the experimental field was fairly uniform and infested with location-specific weeds representative of this area. The soil was clayey, neutral (pH 7.20), medium in organic carbon (0.64%), normal in electrical conductivity (0.32 dS/m), medium in available N (370.0 kg/ha) and P (16.0 kg/ha) and high in available K (295 kg/ha). Twenty treatment combinations, consisting of 5 moisture levels 100, 95, 90, 85 and 80% available soil moisture (ASM) and 4 weed control practices, viz.weedy check, isoproturon 0.75 kg/ha, clodinafop alone 0.06 kg/ha and clodinafop 0.06 kg/ha followed by 2,4-D 0.50 kg/ha were laid out in split-plot design and replicated 4 times. Wheat 'GW 273' was sown with seed rate of 125 kg/ha during both the years. The crop was sown on 6 December and 27 November and harvested on 1 April and 29 March during 2008–09 and 2009–10 respectively. Fertilizers were given uniformly to all the plots through urea, single superphosphate and muriate of potash at the rate of 100 kg nitrogen, 60 kg phosphorus and 40 kg potash/ha during both the years. Half of the nitrogen and full quantity of phosphorus and potash were given basal and remaining nitrogen was given in two splits-just next day of first and second irrigation in both the years. Five irrigations were given to the crop at all the critical stages, viz. crown-root initiation, maximum tillering, late jointing, flowering and milk stages. However, a shallow come-up irrigation was given immediately after sowing to the wheat crop in all the plots. The soil moisture maintained during the herbicidal application by 6050×3K1 minitrace kit soil moisture meter after the first irrigation up to 15 cm depth. The 100% available soil moisture which was recorded at the second day of first irrigation was considered as field capacity. Moisture observation recorded daily and with the depletion of moisture from 100% to every 5%, herbicidal spray was done up to 80% ASM. The ASM at 100, 95, 90, 85 and 80% was registered on day 2, 5, 9, 11 and 13 day after first irrigation. Herbicides were applied in the respective plots by knapsack sprayer using flat-fan nozzle. The NPK depletion by weeds was estimated 50 days after sowing and nutrient uptake by crop at harvest.

RESULTS AND DISCUSSION

Weed infestation

The wheat crop was mainly invaded with grassy weeds particularly *Dinebra retroflexa* (Vhal) Panzer (31.86 and 29.34%), *Cyperus rotundus* L. (15.03 and 18.73%) and *Phalaris minor* Retz. (9.72 and 7.12%); and dicot weeds *Cichorium intybus* L. (8.52 and 8.74%) *Medicago hispida* Gaertn. (7.62 and 8.86%), *Alternanthera philoxeroides* (Mart.) Griseb. (7.41 and 8.61%), *Melilotus indica* L. (6.41 and 5.87%), *Anagallis arvensis* L. (5.31 and 4.62%), *Chenopodium album* L. (4.11 and 4.62%) and *Trifolium fragiferum* L. (4.01 and 3.50%) during both the years.

Application of herbicide at 100% available soil moisture showed significantly lowest weed density (9.4/m^2) and total dry weight of weeds (6.5 g/m^2) during both the years and proved significantly superior to 85 and 80% ASM (Table 1). The density and dry weight of weeds was minimum at 100% ASM during herbicidal application followed by 95 and 90% ASM due to less time period for germination and emergence of weed seedlings. However, every 5% decrease in moisture level at herbicide application provided more time for weed seed germination and emergence that mainly contributed towards higher density of weeds in plots having 80% ASM at the time of herbicides application. Similar findings were also been reported by Imanat (2002).

Among weed-control practices, post-emergence application of clodinafop followed by 2,4-D resulted in significantly lowest total weed density and dry weight during both the years than isoproturon, clodinafop and weedy check. Isoproturon and clodinafop were also equally effective in reducing the total weed density and dry weight and proved significantly superior to the weedy check (Table 1). Excellent control of both grassy and broad-leaf weeds due to sequential application of grass killer (clodinafop) and broad leaf killer (2,4-D) is the reason for minimal total weed density and total weed biomass. Broad-spectrum weed control by isoproturon and better control of grassy weeds by clodinafop could be the reason for superiority of both the herbicides as against weedy check (Punia *et al*. 2003; Mishra, 2006).

The weed-control efficiency was higher at 100% ASM at the time of herbicides application and it was declined with every 5% decrease in available soil moisture at the time of herbicides application, being the minimum (34.0%) under 80% ASM. The application of clodinafop followed by 2,4-D registered significantly higher weed-control efficiency over isoproturon and clodinafop alone.

Yield attributes and grain yield of wheat

Effective tillers/m^2, grains and test (1,000-grains) weight decreased with every 5% decrease in available soil-moisture levels. Application of herbicides at 100% ASM registered significantly higher number of effective tillers, number of grains/ear and test weight than 85 and 80% ASM but were at par with 95 and 90% ASM (Table 1).

The presence of 100% ASM at the time of herbicide application registered significantly higher grain yield of wheat and proved significantly superior to 85 and 80% ASM, but was found at par with 95 and 90% ASM (Table 2). Imanat (2002) evaluated the efficiency of clodinafop-proprargy applied at different soil moisture regimes and reported that number of tillers, number of grains/spikes, 1,000-grain weight and grain yields as well as net income were significantly higher when herbicides were applied at at higher moisture levels, however grain yield was reduced significantly when applied at lower moisture levels. Dinkar and Ahuja (1987) also reported importance of soil moisture at the time of herbicide application for increasing yield

Post-emergence application of clodinafop followed by 2,4-D, isoproturon and clodinafop did not differ significantly in number of effective tillers/m^2, number of grains/ear and test weight and these proved significantly superior to weedy check which had minimum number of effective tillers, grains/ear and test weight.

Among the weed-control treatments, clodinafop followed by 2,4-D proved significantly superior and resulted in 4.9 and 6.5% higher grain yield than isoproturon and clodinafop, and 18.0% higher over weedy check. Clodinafop followed by 2,4-D applied as post emergence showed knockdown effect on grassy and broad leaved weeds which resulted in increased crop growth, yield attributes and finally grain yield of wheat. Similar results were also obtained by Brar and Walia (2007) and Jain *et al.* (2007). Application of isoproturon resulted in higher grain yield of wheat than clodinafop; however, the differences were not significant. This was due to control of both grassy as well as some broad-leaf weeds by the application of isoproturon.

Among interactions, application of all the post-emergence herbicides had significantly higher grain yield at 100% available soil moisture (100% ASM) over 85 and 80% ASM but found statistically similar to 95 and 90% ASM. The higher activity of herbicidal treatments against

Table 1. Effect of moisture levels at the time of herbicides application and weed control on total weed density, weed biomass, weed control efficiency at 50 days after sowing and yield attributes of wheat (pooled data of 21 years)

Treatment	Total weed density/m^2	Total weed biomass (g/m^2)	Weed-control efficiency (%)	Effective tillers/m^2	Grains/ear	Test weight (g)
Moisture level						
100% ASM	9.4 (94.4)	6.5 (44.9)	49.1	280.8	55.3	45.6
95% ASM	9.8 (101.8)	6.7 (47.1)	45.3	268.9	53.8	44.9
90% ASM	10.2 (109.6)	7.0 (49.9)	42.4	262.0	52.4	44.1
85% ASM	11.0 (123.8)	7.3 (53.7)	37.5	255.4	50.7	43.5
80% ASM	11.4 (133.8)	7.5 (57.0)	34.0	250.9	50.0	43.2
SEm ±	0.3	0.2	2.8	6.3	0.9	0.5
CD (P=0.05)	0.9	0.5	8.5	19.4	2.9	1.5
Weed control						
Weedy check	13.3 (179.9)	8.6 (73.6)	0.0	234.8	48.5	42.6
Isoproturon (0.75 kg/ha)	9.9 (100.0)	7.1 (50.3)	32.2	272.7	53.7	44.8
Clodinafop (0.06 kg/ha)	10.3 (108.0)	7.2 (51.6)	29.4	270.5	53.3	44.6
Clodinafop (0.06 kg/ha) *fb* 2,4-D (0.50 kg/ha)	7.8 (62.7)	5.1 (26.6)	63.3	276.5	54.3	45.0
SEm±	0.2 0.1	1.6 2.9	0.7	0.5		
CD (P=0.05)	0.7 0.4	8.4	2.0	1.5		

Data subjected to square root (√x + 0.5) transformation; Figures in parentheses are original values
ASM, Available soil moisture; FB, Followed by

Table 2. Effect of moisture levels at the time of herbicides application and weed control on grain yield (t/ha) of wheat (pooled data of 2 years)

Weed control	Moisture level					Mean
	100% ASM	95% ASM	90% ASM	85% ASM	80% ASM	
W*eedy check*	5.1	5.1	5.0	4.9	4.8	5.0
Isoproturon (0.75 kg/ha)	6.3	6.1	5.8	5.5	5.3	5.8
Clodinafop (0.06 kg/ha)	6.2	6.1	5.7	5.5	5.2	5.7
Clodinafop (0.06 kg /ha) *fb* 2,4-D (0.50 kg/ha)	6.7	6.5	6.1	5.8	5.5	6.1
Mean	6.1	5.9	5.6	5.4	5.2	5.7
	Moisture level (m)		Weed control (w)	m × w at same m		m × w at same w
SEm±	2.0		0.7	1.6		2.4
CD (P=0.05)	6.1		2.0	4.5		7.3

predominant weeds at 100 to 90% ASM curtailed the weed growth identically, which in turn enhanced the availability of growth resources particularly (moisture, nutrients, light, space etc.) and finally resulted in higher grain yield in plots receiving sequential application of clodinafop followed by 2,4-D and by isoproturon and clodinafop alone at 100 to 90% ASM to that of 85 to 80% ASM. However, the reverse was true in case of herbicidal treatments when applied at 85 to 80% ASM. Application of isoproturon and clodinafop was also found equally effective at all the ASM levels and proved significantly superior to weedy check.

Nutrient depletion by weeds

The highest moisture level (100% ASM) showed significantly lower depletion of N, P and K by weeds compared with 85 and 80% ASM (Table 3). However, significant differences among 100, 95 to 90% did not reach to the level of significance. The N, P and K depletion by weeds was more under lower moisture levels (85 and 80% ASM) as a result of more weed density and weed biomass production.

Post-emergence application of clodinafop followed by 2,4-D significantly lowered N, P and K depletion by weeds compared with weedy check, as it had maximum dry weight of weeds. Isoproturon and clodinafop were also effective in reducing the N, P and K depletion by weeds and proved significantly superior to weedy check. The highest removal of NPK under weedy check was obviously attributed to increased weed-biomass production. The reduction in NPK depletion by adopting suitable weed-control practices was reported by Jain *et al.* (2007).

Nutrient uptake by crop

Significant effect of available soil moisture at the time of herbicides application on nitrogen, phosphorus and potassium uptake by crop was observed during both the years. The presence of 100% ASM at the time of herbicides application showed significantly higher N, P and K uptake by grains and straw and proved significantly superior to 85 and 80% ASM, but was found at par 95 and 90% ASM. This was due to higher grain and straw yields of wheat at 100% ASM than that at 85 and 80% ASM. The N, P and K uptake by crop was increased due to post-emergence application of clodinafop followed by 2,4-D (Brar and Walia, 2007) as compared to isoproturon, clodinafop and weedy check. The greater suppression of weeds under clodinafop followed by 2,4-D treated plots favoured higher nutrient uptake by crop owing to more availability of growth resources.

Economics

The highest net monetary returns were recorded under 100% ASM at the time of herbicidal application and these was higher by 16.3 and 22.2% over 85 and 80% respectively (Table 4). Among herbicidal treatments, post-emergence application of clodinafop followed by 2,4-D had significantly higher net monetary return than isoproturon and clodinafop. The higher monetary returns with the post-emergence application of clodinafop followed by 2,4-D

Table 3. Effect of moisture levels at the time of herbicides application and weed control on nutrient depletion by weeds and uptake by wheat (pooled data of 2 years)

Treatment	Nutrient depletion by weeds (kg/ha)			Nutrient uptake by wheat (kg/ha)		
	N	P	K	N	P	K
Moisture level						
100% ASM	4.1	0.7	6.4	98.9	28.4	47.1
95% ASM	4.4	0.7	6.9	94.1	27.0	44.3
90% ASM	4.7	0.8	7.7	92.6	25.0	38.8
85% ASM	5.2	0.8	8.7	86.1	23.6	34.4
80% ASM	6.0	0.9	9.4	80.8	22.0	30.1
SEm±	0.2	0.0	0.4	2.9	1.2	3.3
CD (P=0.05)	0.6	0.1	1.3	9.0	3.6	10.2
Weed control						
Weedy check	7.2	1.1	11.3	80.1	21.9	33.0
Isoproturon (0.75 kg/ha)	4.8	0.8	7.8	93.1	25.9	39.9
Clodinafop (0.06 kg/ha)	4.9	0.8	8.0	91.0	25.5	39.2
Clodinafop (0.06 kg /ha) *fb* 2,4-D (0.50 kg/ha)	2.6	0.4	4.3	97.8	27.5	43.7
SEm±	0.1	0.0	0.3	1.0	0.5	1.2
CD (P=0.05)	0.4	0.1	0.8	2.9	1.4	3.4

ASM, Available soil moisture; FB, Followed by

Table 4. Effect of moisture levels at the time of herbicides application and weed control on economics of wheat (pooled data of 2 years)

Treatment	Net returns ($\times 10^3$ ₹/ha)	Benefit: cost ratio
Moisture level		
100% ASM	60.4	3.9
95% ASM	58.5	3.8
90% ASM	54.4	3.6
85% ASM	52.0	3.5
80% ASM	49.4	3.4
Weed control		
Weedy check	47.9	3.5
Isoproturon (0.75 kg/ha)	57.3	3.8
Clodinafop (0.06 kg/ha)	55.4	3.6
Clodinafop (0.06 kg /ha) *fb* 2,4-D (0.50 kg/ha)	59.2	3.7

ASM, Available soil moisture

over weedy check was also reported by Jain *et al.* (2007).

The benefit: cost ratio was relatively higher under 100% ASM (3.9), followed by 95, 90, 85 and 80% ASM. The higher benefit: cost ratio (3.8) was obtained under isoproturon treatment due to less cost of cultivation (₹ 20.2×10^3/ha) over clodinafop followed by 2,4-D and clodinafop alone. The profitability was minimum under weedy check (3.5) due to improportionate decrease in yield on account of higher crop weed competition. Choudhary *et al*. (2008) also reported higher benefit: cost ratio under clodinafop followed by 2,4-D over weedy check.

It may be concluded that application of clodinafop followed by 2,4-D at 90 to 100% available soil moisture gives higher crop yield and higher monetary returns in herbicidal weed control in irrigated wheat.

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