Indian Journal of Agronomy **65** (2): 231–234 (June 2020)

Research Paper

Chemical weed control in wheat (*Triticum aestivum*) and its residual effects on greengram (*Vigna radiata*)

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Received: February 2020; Revised accepted: June 2020

ABSTRACT

A field experiment was conducted from winter (*rabi*) 2013–14 to rainy season (*kharif*) 2015 on sandy-loam soil, to assess the comparative efficacy of different chemical herbicides and their combinations for effective weed control in wheat (*Triticum aestivum* L.) and their residual effect on succeeding greengram [*Vigna radiate* (L.) R. Wilczek] crop at Instructional Farm, Sumerpur, Rajasthan. The experiment comprised 9 treatments and the herbicides were applied at 30–35 days after sowing (DAS) as prescribed. The application of sulfosulfuron + metsulfuron methyl @ 32 g/ha recorded significantly lower weed dry matter and weed index along with highest weed-control index (76.73 %). This herbicides combination also resulted in the highest grain yield of wheat (3.82 t/ha) along with highest net return and maximum benefit to cost ratio of the system in the tune of 3.4 : 1 as compared to weedy check. The herbicides failed to influence a significant increase on seed yield of succeeding greengram during *kharif* seasons in both years. Uncontrolled weed growth throughout the crop growth period caused an average yield reduction of 57% in wheat crop (2.5 t/ha).

Key words: Economics, Herbicides, Productivity, Wheat-greengram system, Weed parameters

The wheat–greengram is an important cropping system in plains of Luni basin in western Rajasthan. Among wheat-cultivating countries, India has the largest area and the second largest production in world after China. Weed infestation severely limits wheat production and productivity and the losses caused depend on weed types, relative population, environmental factor etc. (Chhokar *et al*., 2012). Weeds are principal biotic constraint in crop production and bring severe interference with normal growth, as they compete for resources like nutrients, moisture, light and space and reduces wheat yield by 37–50% (Waheed *et al.,* 2009). Herbicides on account of their selectivity are most important tools in weed management to sustain yield and quality of crop (Mitra *et al.,* 2019). The chemical method of weed control using effective herbicides proved to be more suitable and economically viable. In western part of Rajasthan, where crop is mostly infested by *Cyperus* sp., *Phalaris minor* Retz. and *Avena sterilis* subsp. *Ludoviciana* (Dur.) Gillet & Magne; syn. *A. ludoviciana* dur., accounts for a major share of total weed quantum causing significant reductions in wheat grain yield (Chhokar *et al.,* 2012). A wide-range yield reduction in wheat on account of weeds is well documented as described by researchers. Few herbicides were most popular and still used to control weeds in wheat showed resistant and changed the scenario of wheat production in India. To broaden the spectrum and to provide the long-term weed control, the use of herbicide mixtures or combinations is advocated to control of complex weed flora. Thus, there is need to work out optimum combination of different herbicides in weed-management practices in wheat so crop can exploit potential of improved varieties under prevailing conditions and their residual effect on widely-grown greengram in region. Considering these facts, an experiment was conducted using new herbicides and herbicide mixtures along with weedy and weed-free checks for weed control in wheat–greengram rotation.

MATERIALS AND METHODS

The experiment was carried out to evaluate the efficacy of different chemical herbicides in wheat and their residual effect on succeeding greengram at the Instructional Farm of Agricultural Research Substation, Sumerpur, Agriculture University (Jodhpur), Rajasthan for 2 consecutive years, i.e. winter (*rabi*) season 2013–14 and *rabi* 2014–15 to rainy season (*kharif*) 2014 and 2015. The soil of experimental sites was sandy loam in texture with good drainage.

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Nine treatments involving different herbicides and their combinations were tested in randomized block design with 3 replications. The wheat crop was sown in the third week of November 2013 and 2014 while greengram was sown in the first fortnight of July 2014 and 2015. The wheat variety 'RAJ 4083' and greengram variety 'GM 4' were used for experimental sowing at recommended seed rate, i.e. 100 and 12 kg/ha respectively. The recommended dose of fertilizers for wheat @ 120 : 40 : 20 kg of N : P_2O_5 : K_2O/ha and 20 : 40 : 40 of N : P_2O_5 : K_2O/ha to greengram were applied through urea, single superphosphate and muriate of potash. The nutrients doses of 40 kg N, 40 kg P_2O_5 and 20 kg K_2O/ha were applied at the time of sowing in wheat crop. The remaining 80 kg N/ha were applied in 2 splits equally after 1st and 2nd irrigations in wheat. The herbicides were applied as per treatments with knapsack sprayer fitted with flat-fan nozzle at 30 days after sowing (DAS). In hand-weeding treatment, only manual weeding was done at regular interval up to 60 DAS. Data were taken through random sampling at harvesting to measure dry-matter accumulation. The crops were harvested as per maturity, i.e. 3rd week of April (wheat) and 2nd week of September (greengram). The weed-control treatments were applied only during the *rabi* season in wheat crop only. The details of treatment are:

T_1, Weedy; T_2, 2, 4-D ethyl ester @ 500 g/ha; T_3, isoproturon @ 800 g/ha; T_4, sulfosulfuron @ 25 g/ha; T_5, metsulfuron-methyl @ 4 g/ha; T_6, sulfosulfuron + metsulfuron-methyl @ 32 g/ha; T_7, clodinafop-propargyl@ 60 g /ha; T_8, clodinafop-propargyl + metsulfuron-methyl @ 60 g/ha; and T_9, weed-free up to 60 DAS.

Weed dry matter was recorded by using quadrate of 0.5 m × 0.5 m at harvesting in all the treatments. The weeds were dried in oven till a constant weight was observed and then converted into kg/ha. The data on weed-dry matter were subjected to square-root transformation to normalize their distribution. Significance differences between the treatments were compared with the critical difference at (5%) probability by LSD (Gomez and Gomez, 1984). To assess the efficacy of different herbicides on crops and weeds, weed-control index (WCI) (Das, 2008) and weed index (WI) were worked out as suggested by Jain *et al.,* (2018).

Weed-control index

It indicates the efficiency of the applied herbicides to control weeds. It is the percentage reduction in weed-dry matter by weed-control treatment in comparison to weedy check plot. Higher the values of WCI, better its performance of the treatment.

$$\text{Weed-control index} = \frac{\text{Weed dry matter in control plot} - \text{weed dry matter in treated plot}}{\text{Weed dry matter in control plot}} \times 100$$

Weed index

It refers to the reduction in crop yield in the presence of weeds in comparison to weed-free crops. It is used to assess the efficacy of herbicide. Lower the value of weed index, better is the efficiency of herbicides.

$$\text{Weed index} = \frac{\text{Yield in weed free plot} - \text{Yield in treated plot}}{\text{Yield in weed free plot}} \times 100$$

Yield and economics

Grain and straw/stover yields were studied as per standard protocols. The total monetary returns (gross returns) of the economic produce obtain from wheat crop and greengram were calculated based on minimum support prices of Government of India.

Net return/ha was calculated by subtracting the total cost of cultivation from the gross returns and benefit: cost ratio (B : C ratio) was calculated as:

B: C ratio = Net income/cost of cultivation

System productivity: System productivity in terms of wheat-equivalent yield (WEY) was calculated using minimum support prices as:

$$\text{System productivity (WEY)} = \text{Wheat yield} + \frac{\text{Yield of greengram} \times \text{Price of greengram}}{\text{Price of wheat}}$$

RESULTS AND DISCUSSION

Weed-control index and weed index

The weedy plots were infested with the highest densities of weed species like *Phalaris minor* and *Avena sterilis* subsp. *Ludoviciana;* syn. A. *ludoviciana* among grassy weeds and *Rumex retroflexus* Lag., *Malva parviflora* L., *Melilotus alba* Medik., *Vicia sativa* L., *Chenopodium album* L., *Lepidium didymium* L.; syn. *Coronopus didymus* Swine, *Anagallis arvensis* L., and *Convolvulus arvensis* L. along with many other broad-leaved weeds frequently started infesting wheat fields. Higher weed-control index was recorded in weed-free check at 60 DAS, followed by application of sulfosulfuron + metsulfuron methyl @ 32 g/ha (76.45%) and treatment clodinafop-propargyl + metsulfuron-methyl @ 60 g/ha (68.70%). The higher weed-control index under these treatments was reflected due to lower dry weight of weeds. Weed index is indirectly related to the reduction in yield due to weed population or weed dry weight. Weed-free check and herbicide application with sulfosulfuron + metsulfuron methyl @ 32 g/ha recorded the minimum weed index, and was followed by clodinafop-propargyl + metsulfuron-methyl @ 60 g/ha at 30 DAS (Table 1). These was significantly superior to all the other treatments in reducing total weed count and total weed dry weight along with grain yield during both year.

Hand-weeding twice up to 60 DAS removed the weeds completely and created conditions which were more favourable for crop growth, and ultimately resulted in the lowest weed biomass during the crop-growth period (Singh *et al.,* 2018). Further, they stated that the lower dry matter of weeds by herbicides may be ascribed to broad-spectrum activity of herbicidal combination, particularly on emergence of both broad-leave and grassy weeds and its greater efficiency to retard cell-division of meristems causing rapid drying of weeds.

Yield attributes and yields

Wheat

Application of herbicides in wheat resulted in a significant increase in all yield components in wheat (Table 2). Maximum number of tillers, spikes/plant and 1000-grain weight found with application of sulfosulfuron+ metsulfuron methyl @ 32 g/ha and was 13.0, 6.7 and 42 g respectively. This might be owing to the fact that application of herbicides maintained a weed-free crop environment and resulted in the availability of critical inputs for long period and highest number of productive tillers per unit area (Rana *et al.,* 2017).

Grain and straw yields of wheat varied significantly among the treatments.The results revealed that the grain yield of wheat was found to be maximum under 2 hand-weeding up to 60 DAS in both the years, closely followed by sulfosulfuron + metsulfuron-methyl (premixed) @ 32 g/ha. The treatment, sulfosulfuron + metsulfuron-methyl (pre-mixed) @ 32 g/ha gave the highest pooled seed yield of 3.82 t/ha, followed by clodinafop propargyl + metsulfuron methyl @ 60 g/ha (3.41 t/ha). All the treatments applied to control weeds resulted in significant enhancement in mean straw yields of wheat. Besides weed-free check, the treatment sulfosulfuron + metsulfuron methyl (pre-mixed) @ 32 g/ha registered significantly higher mean straw yields (5.47 t/ha), closely followed by clodinafop-propargyl + metsulfuronmethyl @ 60 g/ha (5.04 t/ha). The similar trend was found in both the years in respect of grain and straw yields. Chahal *et al.* (2003) also reported 54% higher grain yield of wheat over unweeded check with the application of clodinafop-propargyl.

In restricted weed environments, improved resource use due to herbicide treatments might have led to a significant yield advantage, increased uptake of nutrients and might have provided better rooting and ground cover as well as higher water-use efficiency (Banerjee *et al.,* 2018). Also, the weed-management treatments might have significantly reduced the uptake of nutrients by weeds, which concurrently provided better environment for crop-growth characteristics and yield attributes (Kien *et al.,* 2016).

Residual effect on greengram

Different weed-management practices or application of different herbicides applied to wheat did not cause any adverse effect on yield of succeeding greengram crop on pooled mean of 2 years (Table 2). Grain and stover yields of succeeding greengram, showed a non-significant enhancement with residual effect of weed-control measures in preceding wheat crop. The treatments which exhibited the best efficacy in wheat also resulted in the highest seed yield of greengram. The maximum seed yield was recorded with hand-weeding treatment, followed by sulfosulfuron + metsulfuron-methyl @ 32 g/ha (3.82 t/ha). The application of tested herbicides at different doses in the previous wheat crop did not leave any phytotoxic effect on the succeeding crop greengram (Beenrajee *et al.,* 2019).

System productivity

The yield attributes in wheat was significantly higher under wheat–greengram cropping system under irrigated conditions (Tables 2), which contributed towards significant variation in system productivity. However, herbicide

Table 1. Effect of chemical weed-control treatments on weed parameters in wheat crop (2 years pooled data)

	Treatment	Weed dry-matter (kg/ha)	Weed control index (%)	Weed index (%)
T_1	Control	786.95	0	36.3
T_2	2, 4-D ethyl ester @ 500 g/ha	578.97	26.43	28.5
T_3	Isoproturon @ 800 g/ha	357.91	54.52	19.3
T_4	Sulfosulfuron @ 25 g/ha	572.13	27.30	27.7
T_5	Metsulfuron-methyl @ 4 g/ha	358.73	54.41	19.2
T_6	Sulfosulfuron + metsulfuron-methyl @ 32 g/ha	183.12	76.73	2.9
T_7	Clodinafop-propanyl @ 60 g /ha	478.73	39.17	24.5
T_8	Clodinafop-propargyl + metsulfuron-methyl @ 60 g a.i./ha	247.99	68.49	13.1
T_9	Weed-free check up to 60 DAS	0	100.00	0
	SEm±	10.9		
	CD (P=0.05)	32.7		

DAS, Days after sowing

Table 2. Yield and economics of wheat, greengram and the wheat–greengram system (*rabi* 2013–14 to *kharif* 2015) (pooled 2 years of data)

Treatment		Yield attributes in wheat: Tillers/ plant	Spikes/ plant	1000-grain weight (g)	Wheat seed yield (t/ha)	Wheat straw yield (t/ha)	Greengram seed yield (t/ha)	System yield (t/ha)	Cost of cultivation of wheat (× 10^3 ₹/ha)	Net return from wheat (×10^3₹/ha)	Net benefit: cost (Wheat)
T_1	Control	9.8	4.3	40.50	2.50	4.06	0.38	4.06	17.23	39.34	2.3
T_2	2, 4-D ethyl ester @ 500 g/ha	11.7	4.3	41.00	2.81	4.24	0.40	4.42	18.03	43.91	2.4
T_3	Isoproturon @ 800 g/ha	12.3	5.0	41.33	3.17	4.73	0.41	4.85	18.13	51.47	2.8
T_4	Sulfosulfuron @ 25 g/ha	12.0	4.3	41.33	2.84	4.28	0.40	4.47	18.51	44.10	2.4
T_5	Metsulfuron-methyl @ 4 g/ha	12.3	5.0	41.33	3.17	4.70	0.39	4.77	17.98	51.54	2.9
T_6	Sulfosulfuron + Metsulfuron-methyl @ 32 g/ha	13.0	6.7	42.00	3.82	5.47	0.42	5.56	18.68	63.96	3.4
T_7	Clodinafop-propanyl @ 60 g/ha	12.3	4.7	41.17	2.97	4.49	0.40	4.60	18.26	47.22	2.6
T_8	Clodinafop-propargyl + Metsulfuron methyl @ 60 g.i./ha	12.7	5.0	41.67	3.41	5.04	0.42	5.12	18.78	55.91	3.0
T_9	Weed-free check up to 60 DAS	13.0	6.7	42.67	3.93	5.38	0.46	5.81	21.55	62.31	2.9
	SEm±	0.70	0.24	0.57	0.12	0.15	0.015	0.13	–	18.75	0.11
	CD (P=0.05)	NS	0.73	NS	0.35	0.45	NS	0.37	–	56.22	0.31

applied in wheat crop did not have any significant effect on yield of greengram grown after wheat. The highest system productivity of 5.56 t/ha as compared to weedy check (0.87 t/ha) was observed in treatment sulfosulfuron + metsulfuron methyl (premixed) @ 32 g/ha.

Economics

All weed-control treatments recorded higher net returns and net benefit: cost ratio over the weedy check in wheat crop under study (Table 2). Further, the treatment sulfosulfuron + metsulfuron-methyl (premixed) @ 32 g/ha gave highest system economic net return and maximum net benefit: cost of 3.4: 1 as compared to the control. However the treatment clodinafop-propargyl + metsulfuron-methyl @ 60 g /ha did not show its economic superiority because of higher cost of herbicide. Unweeded plots gave the lowest monetary returns in both the years due to poor crop yields (Beenrajee *et al.,* 2019). The higher seed yield recorded with this treatment might be responsible for higher net returns. These findings are in close vicinity with those reported by Singh *et al. (*2018).

From these findings it is clear that the combinations of sulfosulfuron + metsulfuron-methyl 32 g/ha at 30 DAS a may be suggested for weed control in wheat in western zone of Rajasthan for getting higher yield when there is scarcity of labour.

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