The Pharma Innovation Journal 2023; 12(5): 2371-2374

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(5): 2371-2374

www.thepharmajournal.com
Received: 08-03-2023
Accepted: 12-04-2023

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Bio-efficacy of clodinafop propargyl alone and in combination with other herbicides against weed dynamics in wheat (*Triticum aestivum* L.)

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Abstract
A field experiment was conducted during the *rabi* season of 2021-22 at Research Farm A, College of Agriculture, Ganj Basoda, District Vidisha (M.P.). Result indicated that all the treated plots significantly reduced the weed population and dry weight over untreated control. At 30 DAS, lowest weed population, weed dry weight and weed index was found under hand weeding. Highest weed control efficiency (95.43%) and grain yield was also recorded with hand weeding. Among the herbicidal application, post-emergence herbicide clodinafop propargyl + metsulfuron methyl @ 60 + 4 g a.i.ha^{-1} reduced significantly the weed population, dry weight and weed index while highest weed control efficiency (85.26%) and grain yield (4854 kg ha^{-1}) to over all the herbicidal treatments but found at par with clodinafop propargyl + metribuzin @ 60 + 175 and clodinafop propargyl + carfentrazone ethyl @ 60 + 20 g a.i. ha^{-1}.

Keywords: Post emergence, clodinafop propargyl, weed flora, weed control efficiency, wheat

Introduction
Wheat (*Triticum aestivum* L.) plays an important role in ensuring global food security by feeding billions of people and providing half of their dietary protein and more than half of their calories (Meena *et al.*, 2017) [7]. Wheat is mostly high in carbohydrates, but it also contains significant amounts of other nutrients like protein, fat, minerals, and vitamins. In addition to its nutritious value and greater protein content than other cereals, it also has gluten protein that bakers need. It is very important for farmers and the Indian economy, hence there is a need to raise wheat's productivity level. It makes about 25 per cent of the nation's total grain production and is the second most important food crop after rice in terms of consumption.
Weed management techniques play a key role in improving productivity of wheat. If weeds germinate with the emerging crop-seedlings and are not controlled in the early phases of crop growth, yields can be reduced by 10 to 40 per cent depending on the intensity and kind of weeds present in the area. Wheat yield was reduced by more than 60 per cent due to a mixed population of *Phalaris minor* and *Chenopodium album* (Singh and Singh, 2005) [14]. Therefore, control of mixed weed flora of wheat is most important for enhancing the wheat yield. Weeds compete with the crop for moisture, nutrients, space, light and other resources, which is one of the main reasons for wheat's low yield. Additionally, they raise the cost of production, diminish crop yield, harbour pests and plant diseases, degrade the quality of agricultural output and lower land values. Henceforth, weeds are to be controlled in time to get rid of weed menace during crop season. Presently, weeds are being controlled mainly by herbicides. Continuous application of single herbicide leads to development of resistance in weeds and also all sort of weeds is not being controlled. Therefore, farmers are using ready mixture or tank mixed herbicides for effective control of weeds in wheat. Since clodinafop propargyl, metribuzin, metsulfuron methyl and carfentrazone ethyl are being used for weed control in wheat.

Material and Methods
The field experiment was carried out during the *rabi* season of 2021-22 at the Research Farm A, College of Agriculture, Ganj Basoda, District Vidisha (M.P.) (23^0 51' N, 77^0 55' E and at 416.66 m above mean sea level).The experimental site is characterized by sub-humid with hot dry summers and cool dry winters. The average annual rainfall in Vidisha district is 1135 mm, with most of it falling between mid-June and the end of September, with a little and occasional rains in the other months of the year.

The soil in the Ganj Basoda district Vidisha region is classed as Vertisol. The depth ranges from medium to deep and the colour is black. Nine treatments viz.T_1- clodinafop propargyl, T_2- metsulfuron methyl, T_3- carfentrazone ethyl, T_4- metribuzin, T_5- clodinafop propargyl+ metsulfuron methyl, T_6- clodinafop propargyl + carfentrazone ethyl, T_7- clodinafop propargyl + metribuzin,T_8-hand weeding at 30 DAS and T_9- weedy check were tested in randomized block design with three replications. Wheat variety HI-1544 (Purna) was treated with fungicide (Tebuconazole @ 2.5 g/kg seed) sown on 16th November, 2021at 20 cm apart using 100 kg seed/ha. The crop was harvested on 21st March, 2022. All the herbicides were applied by knapsack sprayer fitted with flat fan nozzle using spray volume of 500 litre/ha. All the herbicides were sprayed at 25 DAS of wheat crop as post emergence whereas, hand weeding was done at 30 DAS with the help of Khurpi. Weed population was recorded by using 0.25 m^2quadrate at30 and 60 DASin all the treatments. The weeds were dried in oven till a constant weight was observed and then converted in to kg/ha. The data on total weed count was subjected to square root transformation *i.e.*, $\sqrt{(x + 0.5)}$ to normalize their distribution (Gomez and Gomez, 1984) [3]. Weed control efficiency (Mani *et al.*, 1973) [6] and weed index (Gill and Kumar, 1969) [2] were worked out by given formula:

$$\text{WCE (\%)} = \frac{\text{Dry weight of weeds in weedy check - Dry weight of weeds in treated plot}}{\text{Dry weight of weeds in weedy check}} \times 100$$

$$\text{Weed index (\%)} = \frac{\text{Yield of weed free plot - Yield of treated plot}}{\text{Yield of weed free plot}} \times 100$$

Results and Discussion

Weed flora

The experiment field was infested with grassy, broad-leaf weeds and sedges. Among the broad-leaf weeds, *Convolvulus arvensis* (23.30%), *Chenopodium album* (16.77%), *Anagallis arvensis* (16.23%) and *Parthenium hysterophorus* (7.14%) were the dominant weeds. Dominant grassy weeds that invade the field were *Phalaris minor* (9.48%) and *Cynodon dactylon* (13.71%). Wheat crop field was also invaded by sedges *i.e.*, *Cyperus rotundus* which had relative density in weedy check 13.38per cent.

Effect on density and dry weight of weeds

The density and dry weight of *Phalaris minor, Cynodon dactylon, Convolvulus arvensis, Chenopodium album, Anagallis arvensis, Parthenium hysterophorus* and *Cyperus rotundus* at 60 DAS, were shown in Table 1 and 2. The data revealed that when the weeds were controlled manually or chemically, the density and dry weight was reduced as compared to weedy check treatment, where weed management practices were not done. The application of clodinafop propargyl + metsulfuron methyl controlled both grassy and broad-leaved weeds effectively and in some context sedges and gave lowest weed density and dry weight than other herbicidal treatments. The application of clodinafop propargyl + metribuzin and clodinafop propargyl + carfentrazone ethyl also controlled grassy, broad-leaf weeds and sedges. The application of carfentrazone ethyl was very effective broad-leaf weeds specially *Convolvulus arvensis* because it translocates throughout the plant systems and acts as an inhibitor of amino acid biosynthesis, hence stopping cell division and plant growth. Metsulfuron methyl and carfentrazone ethyl controlled broad-leaf weeds and was almost ineffective against grassy weeds. Metribuzin controlled broad-leaf and some grassy weeds. Clodinafop propargyl controlled grassy weeds effectively and almost least effective against broad-leaved weeds. In prior art of research, similar trends of results were also reported by Kaur *et al.* (2015) [4], Sandhu *et al.* (2016) [11] and Chaudhary *et al.* (2017) [1]. Hand weeding at 30 DAS lowered down the population and dry weight of all the weeds to the maximum extent as compared to herbicidal treatments. This may be assigned to the extent of crop weed competition stress mainly for light, nutrient, moisture, and space under comparatively weed free environment an individual plant had more favourable growing conditions, conductive to better overall expression than otherwise. This was in accordance with the findings of Singh *et al.* (2015) [15] and Rasool *et al.* (2017) [10].

Table 1: Density of weeds m^{-2} at 60 DAS as influenced by different weed control treatments in wheat

Treatments details	Grasses		Broad-leaf weeds				Sedges
	Phalaris minor	*Cynodon dactylon*	*Convolvulus arvensis*	*Chenopodium album*	*Anagallis arvensis*	*Parthenium hysterophorus*	*Cyperus rotundus*
T_1-Clodinafop Propargyl @ 60 g a.i./ha	1.35 (1.33)	1.42 (1.52)	5.20 (26.54)	4.43 (19.13)	4.32 (18.13)	3.17 (9.54)	2.32 (4.87)
T_2-Metsulfuron Methyl @ 4 g a.i./ha	3.66 (12.91)	4.13 (16.58)	1.71 (2.43)	1.82 (2.81)	1.82 (2.83)	1.48 (1.68)	4.02 (15.66)
T_3-Carfentrazone Ethyl @ 20 g a.i./ha	3.69 (13.14)	4.18 (17.00)	1.54 (1.86)	1.90 (3.11)	1.90 (3.11)	1.73 (2.51)	4.06 (16.00)
T_4-Metribuzin @ 210 g a.i./ha	3.12 (9.22)	2.71 (6.84)	1.49 (1.71)	1.95 (3.32)	1.99 (3.46)	1.42 (1.52)	2.40 (5.24)
T_5-Clodinafop Propargyl + Metsulfuron Methyl @ 60+4 g a.i./ha	1.26 (1.10)	1.32 (1.25)	1.39 (1.44)	1.70 (2.40)	1.69 (2.34)	1.36 (1.36)	2.28 (4.72)
T_6-Clodinafop Propargyl + Carfentrazone Ethyl @ 60+20 g a.i./ha	1.33 (1.28)	1.37 (1.37)	1.44 (1.57)	1.83 (3.86)	1.87 (3.00)	1.59 (2.04)	2.33 (4.93)
T_7-Clodinafop Propargyl + Metribuzin @ 60+175 g a.i./ha	1.30 (1.18)	1.33 (1.28)	1.36 (1.36)	1.86 (2.95)	1.79 (2.69)	1.24 (1.03)	2.21 (4.40)
T_8-Hand weeding at 30 DAS (Once)	1.11 (0.74)	1.05 (0.60)	1.08 (0.66)	1.17 (0.86)	1.03 (0.57)	1.09 (0.68)	1.11 (0.74)
T_9-Weedy check	3.71 (13.27)	4.20 (17.15)	5.32 (27.78)	4.44 (19.25)	4.37 (18.57)	3.18 (9.63)	4.08 (16.15)
SEm±	0.15	0.14	0.20	0.19	0.20	0.13	0.07
CD at 5 %	0.46	0.42	0.60	0.57	0.59	0.38	0.20

Arcsin$\sqrt{(x + 0.5)}$ transformed values, original values are shown in parenthesis

Table 2: Dry weight of different weeds (g m^{-2}) at 60 DAS as influenced by different weed control treatments in wheat

Treatments details	Grasses		Broad-leaf weeds				Sedges
	Phalaris minor	*Cynodon dactylon*	*Convolvulus arvensis*	*Chenopodium album*	*Anagallis arvensis*	*Parthenium hysterophorus*	*Cyperus rotundus*
T_1-Clodinafop Propargyl @ 60 g a.i./ha	1.44 (1.57)	1.77 (2.63)	4.73 (21.83)	5.16 (26.10)	5.01 (24.57)	5.07 (25.17)	3.23 (9.91)
T_2-Metsulfuron Methyl @ 4 g a.i./ha	3.98 (15.31)	4.27 (17.74)	1.58 (2.00)	2.08 (3.84)	2.09 (3.85)	2.25 (4.55)	5.65 (31.47)
T_3-Carfentrazone Ethyl @ 20 g a.i./ha	4.01 (15.59)	4.31 (18.10)	1.44 (1.56)	2.18 (4.26)	2.18 (4.26)	2.64 (6.49)	5.73 (32.33)
T_4-Metribuzin @ 210 g a.i./ha	3.39 (10.96)	2.92 (8.00)	1.39 (1.42)	2.24 (4.54)	2.29 (4.75)	2.10 (3.93)	3.33 (10.60)
T_5-Clodinafop Propargyl + Metsulfuron Methyl @ 60+4 g a.i./ha	1.35 (1.32)	1.69 (2.36)	1.37 (1.38)	1.94 (3.25)	1.92 (3.18)	1.99 (3.48)	3.20 (9.76)
T_6-Clodinafop Propargyl + Carfentrazone Ethyl @ 60+20 g a.i./ha	1.41 (1.50)	1.74 (2.54)	1.34 (1.30)	2.10 (3.89)	2.14 (4.08)	2.42 (5.34)	3.24 (10.03)
T_7-Clodinafop Propargyl + Metribuzin @ 60+175 g a.i./ha	1.39 (1.42)	1.71 (2.42)	1.27 (1.12)	2.13 (4.02)	2.04 (3.60)	1.79 (2.71)	3.06 (8.87)
T_8-Hand weeding at 30 DAS (Once)	1.17 (0.88)	1.42 (1.51)	1.02 (0.55)	1.21 (0.96)	1.13 (0.78)	1.47 (1.65)	1.36 (1.34)
T_9-Weedy check	4.11 (16.38)	4.34 (18.37)	4.83 (22.87)	5.19 (26.43)	5.09 (25.44)	5.12 (25.73)	5.75 (32.52)
SEm±	0.16	0.18	0.17	0.19	0.14	0.19	0.16
CD at 5 %	0.47	0.55	0.50	0.58	0.42	0.58	0.47

Arcsin√ (x + 0.5) transformed values, original values are shown in parenthesis

Table 3: Weed control efficiency, weed index and grain yield of wheat as influenced by different weed control treatments

Treatment details	Weed control efficiency (%)	Weed index (%)	Grain yield (kg ha^{-1})
T_1-Clodinafop Propargyl @ 60 g a.i./ha	33.36	20.53	3987
T_2-Metsulfuron Methyl @ 4 g a.i./ha	53.05	15.29	4250
T_3-Carfentrazone Ethyl @ 20 g a.i./ha	50.76	17.10	4159
T_4-Metribuzin @ 210 g a.i./ha	73.65	13.37	4346
T_5-Clodinafop Propargyl + Metsulfuron Methyl @ 60+4 g a.i./ha	85.26	3.25	4854
T_6-Clodinafop Propargyl + Carfentrazone Ethyl @ 60+20 g a.i./ha	82.90	10.66	4482
T_7-Clodinafop Propargyl + Metribuzin @ 60+175 g a.i./ha	85.06	7.02	4665
T_8-Hand weeding at 30 DAS (Once)	95.43	0.00	5017
T_9-Weedy check	0.00	36.72	3175
SEm±	-	-	44.23
CD at 5 %	-	-	132.60

Arcsin√ (x + 0.5) transformed values, original values are shown in parenthesis

Weed control efficiency

Weed control efficiency (WCE) of a treatment has strong negative relationship with weed biomass. Among herbicidal treatments, application of clodinafop propargyl + metsulfuron methyl had highest weed control efficiency (85.26%) as compared to any other treatments in case of grassy, broad-leaf and sedges weeds which was followed by the application of clodinafop propargyl + metribuzin and clodinafop propargyl + carfentrazone ethyl. These pre-mix herbicides significantly reduced the population and dry weight of grassy, broad-leaf and sedges weeds. This was the main cause of higher WCE. Hand weeding at 30 DAS resulted in weed free environment with highest weed control efficiency (95.43%) because it eradicated all types of weeds (Table 3). Similar findings were also reported by Pisal and Sagarka (2013) [8], Shyam *et al.* (2014) [13] and Singh *et al.* (2015) [15].

Weed index

The weedy check plot resulted in maximum reduction (36.72%) of yield due to presence of weeds throughout the crop growing period as compared to hand weeding. The application of treatments, clodinafop propargyl + metsulfuron methyl resulted in lowest yield reduction (3.25%) which proved to be superior over all the herbicidal treatments. It was tailed by clodinafop propargyl + metribuzin (7.02%). The third-best treatment was clodinafop propargyl + carfentrazone ethyl (10.66%) weed index (Table 3). This was happened due to reduction in weeds because of effective weed management throughout the critical period of crop growth under these treatments. This resulted in minimal decrease in grain yield. These findings are in accordance with those of N. Ramesh (2013) [9], Choudhary *et al.* (2017) [1] and Shaktawat *et al.* (2019) [12].

Grain yield

The data pertaining to grain yield (kgha^{-1}) as affected by different treatments are given in Table 3.Under hand weeded plot, the highest grain yield (5017 kg ha^{-1}) was secured.In case of herbicidal treatments, clodinafop propargyl + metsulfuron methyl produced highest grain yield (4854 kg ha^{-1}) and proved to be significantly superior to other herbicidal treatments. However, the second-best treatment was clodinafop propargyl + metribuzin producing 4665 kg ha^{-1} grain. The third-best treatment was clodinafop propargyl +

carfentrazone ethyl. Weedy check treatment produced the lowest grain yield (3175 kg ha^{-1}).Similar findings were also observed by Kumar *et al.* (2011) [5], Chaudhary *et al.* (2017) [1] and Shaktawat *et al.* (2019) [12].

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