Research Article | Open Access

Karim et al., 2022. 24 (1&2): 10-17. J. Environ. Agric. Sci. (ISSN: 2313-8629)

Comparative Efficacy of Different Post-Emergence Herbicides for Controlling Broad Leave Weeds in Wheat Under Agro-Ecological Conditions Of Dera Ghazi Khan, Pakistan

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Received
February 22, 2022
Accepted
May 10, 2022
Published Online
June 28, 2022

Abstract: The efficacy of various post-emergence herbicides (T1), aminoclopyrald + Floraxypyre (cleanwave150 EC) @ 800 ml /ha, (T2), Fluroxypryre+ MCPA (strain M 50 EC) 750 ml/ha, (T3) Clopyrald+ Floraxypyre+ Tribenuraon (whearstar 66 WPG) @ 500g/ha, (T4), Metsulfuran + tribenuran (Allymax @86 SG) @35 g ha^{-1}, (4). Tribenuran methyl (smbex 75 % WGD) @75 g /ha, against a control were checked against broad leave weeds during the crop season Rabi 2019-2020. The experiment was conducted at two different sites of Dera Ghazi Khan, Pakistan, i.e., Taunsa and Kot Chutta with six treatments and conducted in triplicate . The results revealed that broad leaf weed density significantly decrease by all herbicides as compared to control. However, whearstar (T3) were most effective for controlling all these weeds with maximum mortality 80.57 and 78.21 % and weeds control efficiency 96.9% and 98.1% without being phytotoxic to wheat crop. It also proved most significantly better to reduce the weeds biomass as compared to control. Spike bearing tillers (295.13 and 285) , spike length (16.84 and 15.98 cm), number of grains per spike (50.12 and 47.56) and 1000 grain weight (40.16 and 39.42 mg) on both sites, which ultimately enhanced the yield (5924.16 and 5575.4 kg/ha) as compared to control (3248.3 and 2949.7 kg/ha) on both sites.

Keywords: Herbicides efficacy, MCPA, post-emergence herbicides, wheat yield.

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Cite this article as Karim, F., R. Bibi, M.K. Nadeem and Z.Y. Hassan. 2022. Comparative efficacy of different post-emergence herbicides for controlling broad leave weeds in wheat under agro-ecological conditions of Dera Ghazi Khan, Pakistan. Journal of Environmental & Agricultural Sciences. 24(1&2): 10-17.

1. Introduction

Globally wheat is third most produced crop and one of the most imperative food cereals in several countries, including Pakistan, feeding 1.5 million people (Senapati et al., 2022; Zhang et al., 2021). Sustainable wheat production is imperative for regional and global food security (Cole et al., 2018; Grote et al., 2021; Laborde et al., 2020). Total cropped area in Pakistan is 23.80 mha, out of which 17.58 mha is irrigated and 3.96 mha is rainfed (Tahir and Khaliq, 2018). Wheat crop is grown on 9.06 mha with a total annual production of about 25 m tons, with average yield of about 2.83 t ha^{-1} (Mahmood et al., 2019). Wheat is used for making chaptti, bread, biscuit, cakes, pasta, noodles etc. Wheat straw is used to feed livestock, making chipboard, poultry bedding and mixed with mub to spread on the roofs of houses, etc. (Farheen and Naqvi, 2020). Contempt the combined efforts of scientific and farming community, the potential yield i.e (6 t ha^{-1}) could not be achieved still. The gap between the actual and potential yield of wheat is due to many factors like and infestation of insects, diseases and weeds, changing climatic conditions (Alasti et al., 2020; Beza et al., 2017; Khan et al., 2021; Rong et al., 2021). Annual losses caused by weeds in Pakistan caused by infestation of insects, diseases (Iqbal et al., 2019; Khan et al., 2021; Matloob et al., 2020; Mittal,

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2022). Agriculture experts have assumed that weed caused 3 to 13% yield losses in wheat (Flessner et al., 2021) and can reach 40 % (Gharde et al., 2018; Iqbal et al., 2020). Weed infestation is a serious problem affecting the yield of wheat. The statistical range of wheat yield reduction in Pakistan instigated by weeds is about 20-30 % (Abass et al., 2009). They secrete allopathic chemicals in the soil; provide environment for disease causing agent along with the provision of additional host for several insects and rise the cost harvesting (Bashar et al., 2021; Mahe et al., 2022; Xie et al., 2021).

These are prompt reducing the crop yield, not only through competing factors for plant growth (Space, light, CO_2, Soil moisture and Nutrients) and development (Adeux et al., 2019; Little et al., 2021; Petit et al., 2011). Moreover, weeds also release certain allelochemicals form the root zone and other parts of plants into the roots of desired crop plants (Li et al., 2019; Jabran et al., 2015; Radicetti and Mancinelli, 2021). Herbicides efficiently control weeds and improve the grain yield of crops (Hussain et al., 2021). Weed managing is a decision-making process based on the basic ideologies of science that bring together the information of climate, weed life span, i.e flowering and seed set, seeds, newly emerged plant, vegetative growth stages and their relationship to the environment and all accessible approaches for weed management by most cost effective and environmentally justifiable ways. Weed seeds pollute the crop seeds and increase the harvesting cost (Wimalasekera, 2015). Weeds reduce the yield, quality and market value of crop seeds (Shahzad et al., 2021)

Weed management practices comprise manual as well as chemical weed control methods (Blackshaw, et al., 2006). Chemical weed control is preferred as of less labour and no mechanical damage to the crop that occurs throughout manual weeding. Chemical weed control is efficient in producing higher grain yield than hand weeding (Hameed et al., 2019; Monteiro and Santos, 2022; Pavlović et al., 2022; Verma et al., 2021). For gaining efficient results, chemical control can be rapid. Emphasis should be specified on herbicide selection, effective dose of herbicide as the non-judicious use of herbicides can lead to herbicide resistance and decrease crop production instead of improving yield (Matloob et al., 2020; Mishra et a., 2021). Different herbicide companies privilege for effective post-emergence control in wheat by their products, and a lot of work has been done in this regard.

Keeping in view the position of wheat and weeds related problems in changing the environment as well as market circumstances this study might be considered a vital section of weed management. The need of time is to check the relative effectiveness of newly introduced post-emergence herbicidal chemistry for the guidance of the farming community. Keeping all these factors in view the aims of this study were to compare and evaluate the relative efficacy of post-emergence herbicidal chemistry against broad-leaved weeds suppression and to evaluate the growth and establishment of the wheat crop.

2. Materials and Methods

The experiment was conducted in two tehsils of Dera Ghazi Khan division, Pakistan, i.e., Taunsa and Kot chutta at the farm of Changa khan and Rahib Hussain. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications along with 6 treatments. The plot size 21× 10 m^2 comprising of 6 rows of 15 cm was maintained. The recommended fertilizer dose was used. The variety Akbar-2019 was sown with a rabi sowing drill during the 1st fortnight of November, 2019 with recommended seed rate of 125 kg ha^{-1}. All the cultural practices were according to the standards.

Table 1. Description of Treatments

S. No.	Treatment
T_1	Aminoclopyrald + Floraxypyre (cleanwave150 EC) @ 800 ml ha^{-1}
T_2	Fluroxypryre+Mcpa (strain M 50 EC) @ 750 ml ha^{-1}
T_3	Clopyrald+ Floraxypyre + Tribenuraon (whearstar 66 WPG) @ 500g ha^{-1}
T_4	Metsulfuran+tribenuran (Allymax @86 SG) @35 g ha^{-1}
T_5	Tribenuran methyl (smbex 75 % WGD) @75 g ha^{-1}
T_6	Control

Data regarding weeds parameter weed density before and after herbicides application, weeds mortality percentage, weed biomass before and after herbicide application and weeds control efficiency. Weeds were placed sun shine for 4 day and dry matter weight was recorded. Weed control efficiency was calculated using the following formula,

$$\boldsymbol{WCE}\ (\%) = \frac{DMWut - DMWt}{DMWut}\ \text{x}\ 100$$

. (DMWut = Dry matter of weeds from un-treated plots; DMWt = Dry matter of weeds from treated plots.)

$$\textbf{Mortality}\ (\%) = \frac{\text{Wt} - \text{WS}}{\text{Wt}}\ \text{x}\ 100$$

Where Wt= Total number; Ws =Number of surviving weeds.

Wheat parameters germination count m^{-2}, number of tillers^{-2}, Plant hight (cm), spike length (cm), number of grains per spike, 1000 grain weight (g), (biological yield Kg ha^{-1}), grain yield (kg ha^{-1}), grain yield (kg ha^{-1}) and harvest index (%) were also recorded. Weed population was recorded using a quadrate of one square meter, taking two samples from each plot before and after application of treatment and the average was determined. The spike length of ten randomly selected spikes were recorded in centimeters starting from the base to the end of the spike, but not including awns and then the average was calculated for taking spike length. At maturity each plot was harvested, weighed for biological yield and after threshing total grain yield per plot was recorded and then divided by total biological yield of the plot to calculate the harvest index by the following formula.

$$\text{Harvest Index (\%)} = \frac{\text{Total Grain Yield (kg)}}{\text{Biological yield (kg)}} \times 100$$

Statistical analysis

The statistical analysis of mean data was done by using the software STATISTIX 8.1. The least significant difference (LSD) test at 0.05 probability levels was applied to compare the difference among treatments means.

3. Results and Discussion

3.1. Weeds

Following weeds were found in experiment sites: Chenopodium *album* L. (lamsquarters, Bathu), *Cirsium arvense* (L.) (Canada thistle, Leh, Bhur bhur), *Convolvulus arvensis* L. (Field bindweed, Lehli, Baili Wanvehri), *Convolvulus arvensis* L. (Field bindweed, Lehli, Baili Wanvehri, *Emex spinosa* (Lesser jack, Trkandi, Kafar knda), *Fumaria indica* (Fumitory Shahtra, Pitpapra), *Lathyrus aphaca* L. (Wild meadow peavine, Jangli matar, Matri, *Rumex dentatus* L. (Broadleaf dock, bitter dock, Jangli palak, *Trigonella monantha* C.A.(Trefoil Maini), *Vicia tetrasperma* L. (Four seeded vetch Revavri).

3.2. Weed density (m^{-2})

Tables 1 and 2 indicated the related data on which herbicides control the weed maximum. Broadleaf weeds were maximumly suppressed by application of wheat star (19.05 to 4.21 and 29 to 6.33) on both sites. it was statistically much better than weeds controlled by stairn (31.33 to 8.05 and 19.6 to 5.01) , Allymax (21.12 to 6.23 and 32.29 to 9.15) , Cleanwave (20.31 to 6.12 and 30.67 to 8.41), Symbex (22.06 to 7.67 and 31.0 to 9.67) as compared to control (20.16 to 24.33 and 33.35 to 42) in both sites. All the treatments were statistically different from each other and also from the control. Similar results were reported by Sharif et al. (2005), 76% decrease in the weed density with applications of herbicides.

3.3. Weed mortality (%)

Tables 1 and 2 indicate Weeds mortality percentages in response to different post-emergence broad-leaved herbicides. It revealed that more weeds mortality was observed in which wheat star plot (80.57 % and 78.21%) which was statistically at par with stairn M (74.64 and 74.5). These results are in correspondence with the findings of Shahzad et al., (2021), who reported that the weed density significantly decreased through the application of herbicides.

Table 1. Effect of different post-emergence herbicides on weeds characteristics in wheat grown at Tehsil Kot Chuta

	Treatment	Weeds density		Weed mortality	Weeds dry biomass		Weed Control Efficiency
		Pre-spray	Post-spray		Pre-spray	Post-spray	
T1	Aminoclopyrald + Floraxypyre (cleanwave150 EC) @ 800 ml ha^{-1}	20.3 ab	6.1 bcd	70.46 cd	20.27 b	6.44 bc	93.7 c
T2	Fluroxypryre+Mcpa (strain M 50 EC) @ 750 ml ha^{-1}	19.7 ab	5.0 cd	74.64 bc	19.87 b	5.02 cd	95.1 b
T3	Clopyrald+ Floraxypyre + Tribenuraon (whearstar 66 WPG) @ 500g ha^{-1}	19.05 b	4.2 d	80.57 a	14.31 c	3.15 d	96.9 a
T4	Metsulfuran+tribenuran (Allymax @86 SG) @35 g ha^{-1}	21.12 ab	6.3 b	69.68 d	22.61ab	6.11b	93.9 c
T5	Tribenuran methyl (smbex 75 % WGD) @75 g ha^{-1}	22.06 a	7.7 b	40.75 e	22.24 ab	7.54 e	92.6 d
T6	Control	20.16 ab	24.3 a	--	24.06 a	101.53 f	322.5 e

Table 2. Effect of different post-emergence herbicides on weeds characteristics in wheat grown at Tehsil Taunsa

	Treatment	Weeds density		Weed mortality	Weeds dry biomass		Weed Control Efficiency
		Pre-spray	Post-spray		Pre-spray	Post-spray	
T1	Aminoclopyrald + Floraxypyre (cleanwave150 EC) @ 800 ml ha^{-1}	30.7 A	8.33 c	72.4 c	18.7 B	5.92 B	94.2 A
T2	Fluroxypryre+Mcpa (strain M 50 EC) @ 750 ml ha^{-1}	31.3 A	8.0 bc	74.5 bc	15.7 B	3.96 B	96.1 A
T3	Clopyrald+ Floraxypyre + Tribenuraon (whearstar 66 WPG) @ 500g ha^{-1}	29.0 A	6.3 c	78.2 c	8.7 C	1.91 B	98.1 A
T4	Metsulfuran+tribenuran (Allymax @86 SG) @35 g ha^{-1}	32.0 A	9.2 b	71.8 b	18.3 B	4.95 B	95.2 A
T5	Tribenuran methyl (smbex 75 % WGD) @75 g ha^{-1}	31.0 A	9.7 b	71.0 a	18.0 B	6.10 B	94.0 A
T6	Control	33.3 A	42.0 a	--	24.3 A	102.7A	1022.6 B

3.4. Weed dry biomass (gm^{-2})

Weeds dry biomass buildup is an appropriate parameter to evaluate the incompatible nature of weeds for resource utilization and competing with crop plants. Data refer to weed dry biomass in Table 1 and 2, present the maximum weed dry biomass after weeds control as observed in symbex from (22.7 to 7.54 and 18 to 6.10) on both sites. Best treatment Wheatstar showed minimum weed dry biomass from (14.31 to 31 and 8.66 to 1.91) as compared to control (24.06 to 101.5 and 24.33 to 102.69). Other treatments were at par with each other. It clearly shows that herbicides are very effective in suppressing weed biomass compared to control. The results are also in agreement with the findings of Zahoor et al. (2012), who reported that the application of Buctril super significantly reduced the weed dry weight. The highest weed biomass of 40.7g m^{-2} was obtained in the weedy check plots. The results are also in line with the study of Amare et al., 2014, who reported that application of Isoproturon @ 1.00 kg ha^{-1} significantly reduced the dry weed weight in wheat.

3.5. Weed control efficiency (%)

Weed control efficiency (WCE) of various tested treatments in wheat (Table 1 and 2) revealed that all weed control methods exhibited a considerable difference. The maximum weed control efficiency was observed in wheat star (98.1% and 96.9%), stairn M gave less (95.05% and 96.01 %) weed control efficiency in both sites. The least weed control efficiency was measured in the Symbex (92.57 and 94) and clean wave (94.2, 90) in both sites. The results are correlated with the study of Hossain et al. (2009), who reported the reduction in weed dry biomass and consequently drastically increased weed control efficiency by use of herbicides in wheat crop. The results are also in accordance with the work of Singh et al. (2013), who reported that extreme weed control efficiency was found with the use of herbicides in wheat. The results are in also accordance with the findings of Amare et al. (2014) who stated that application of Isoproturon @ 1.00kg ha^{-1} significantly decrease the dry weed biomass, which finally increased the weed control efficiency in wheat.

3.6. Number of tillers (m^{-2})

Tables 3 and 4 depicted the treatments showed a significant effect on the number of wheat tillers m^{-2}. Maximum number of $tiller^{-2}$ were recorded in treatment of wheat star (295, 298) followed by Stairn M (291.2 and 291) in both sites. These treatments were statistically different from each other and rest of treatments. The remaining treatments also produced an almost different number of tillers. The lowest number of tillers m-2 was found in control. Malik et al. (2009) reported that number of tillers significantly improved with the control of broadleaved weeds. Hameed et al. (2019) also concluded that the number of productive tillers are enhanced by control of broadleave weeds.

3.7. Plant height (cm)

Data in table 1 and 2 revealed that the maximum plant height was observed in treatment wheatstar (92.19 cm and 95.38 cm) on both sites followed by the treatment Stairn M 91.33 cm and 92.48 cm). these treatments are statistically different from each other.

Table 3. Effect of different post-emergence herbicides on germination and yield parameters of wheat grown at Tehsil Kot Chuta

	Treatment	Germination (m^{-2})	No of Tillers (m^{-2})	Plant height (cm)	Spike length (cm)	No of grains (m^{-2})	1000 grains weight (mg)	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest Index
T1	**Aminoclopyrald + Floraxypyre (cleanwave150 EC) @ 800 ml ha^{-1}**	174 a	278.1 d	91.7 a	12.5 d	44.7 c	37.3 d	6703 c	4630 C	69.2 A
T2	**Fluroxypyre+Mcpa (Strain M 50 EC) @ 750 ml ha^{-1}**	177 a	291.2 b	91.3 a	13.2 b	47.3 b	39.1 b	7674 b	5422 B	70.6 A
T3	**Clopyrald+ Floraxypyre + Tribenuraon (Whearstar 66 WPG) @ 500g ha^{-1}**	186 a	295.1 a	92.2 a	13.8 a	50.1 a	40.2 a	8247 a	5924A	71.7 A
T4	**Metsulfuran+ tribenuran (Allymax @86 SG) @35 g ha^{-1}**	174 a	287.6 c	89.3 ab	12.9 c	46.2 b	38.2 c	7348 b	5112 B	69.6 A
T5	**Tribenuran methyl (smbex 75 % WGD) @75 g ha^{-1}**	179 a	272.2 e	86.7b	12.3e	43.4 d	35.8 e	6005 d	4523 C	69.4 A
T6	**Control**	180 a	260.3 f	86.7 b	11.3 f	37.7 e	33.1 f	4567 e	3248 D	71.1 A

The smaller plants with height 86.67 and 81.35 cm were noted in the treatment Symbex followed as compared to the control 78.97 and 77.83 cm. the rest of treatments were statistically different from each other and from control. The results of this experiment are in line with the findings of Sherawat et al. (2005) who have reported the similar results and narrated that Atlantis decreased the plant height when applied at recommended rates.

3.8. Spike length (cm)

Spike length were statistically different in all treatment as presented in Tables 3 and 4 in both sites. Maximum spike length (16.84 and 15.98 cm) was obtained with wheat star application followed by Stairn-M (16.15 and 15.73 cm) and Allymax (15.98 and 15.81 cm). Increase in spike length may be due to minimum crop-weeds competition in treated plots as significant weed mortality rate was observed for said treatments. Hameed et al. (2019) and Mahmood et al. (2012) reported maximum spike length due to the reported that maximum spike length. Hameed et al., (2019) have reported similar results for Buctril-super. The minimum spike length (4.00 cm) was recorded against Sectril-M (Borras et al., 2004).

3.9. Number of grains spike^{-1}

The data pertaining to the number of grains spike^{-1} are presented in Table 3 and Table 4. The more number of grains spike-1 were recorded in plots treated with wheat star (50.12, 47.56) as compared to other treatments. It was found at par with Stairn M and Allymas produced grain (46.33. 46.21 and 46.19, 45.78) which were statistically different from each other . It was probably due to better weed control in treated plots that provided a favorable environment to the crop plants to utilize natural resources efficiently for producing a large number of grains spike^{-1}. Hameed et al. (2019) reported more number of grains by use of weedicides in wheat crop under rainfed area.

3.10. 1000-grain weight (g)

Table 1 and 2 data presents significant differences among treatments concerning 1000-grain weight (g). The uppermost 1000-grain weight (40.16 and 39.43 g) was documented in wheatstar followed by Stairn M with 1000 grian weight (39.06 and 38.12 g) in site 1st and 2nd site. While other treatments Allymax and clean wave gave also a significant difference in 1000 grain weight as compared to control. It was due to better utilization of resources and less competion among wheat crop and weeds. Abbas et al. (2009) and Korotkova et al., (2021) observed that weed control by using herbicides increased grain yield in wheat.

3.11. Biological Yield (kg ha^{-1})

Table 3 and 4 depicts that Biological yield of wheat crop is significantly effectd by weedicides spray in all treatments. Higer yield (8247 and 8051 kg/ha) of wheat crop was attained in wheat star plot followed by Stair M plot (7674 and 7668 kg/ha) on both sites. All other treatments were statistically different from each other and also from control. All this happened due to the better performance of herbicide to control weeds, so crop plants from the utilized natural resources effectively and resulted in higer biological yield as compared to control treatments. Amare et al. (2014), reported more biological yield due to the herbicide use.

3.12. Grain yield (kg ha^{-1}) and Harvest Index

Highest grain yield was observed in wheatstar plot (5924.1 and 5575.4) followed by stairn M plot (5422.1 and 5126.9) on both sites as it is presented in M table 1 and 2. Other treatments Allymax and Cleanwave plots also produced grain yield which was statistically different from control and form each other .

Table 4. Effect of different post-emergence herbicides on germination and yield parameters of wheat grown at Tehsil Taunsa

	Treatment	Germination (m^{-2})	No of Tillers (m^{-2})	Plant height (cm)	Spike length (cm)	No of grains (m^{-2})	1000 grains weight (mg)	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest Index
T1	**Aminoclopyrald + Floraxypyre (cleanwave150 EC) @ 800 ml ha^{-1}**	177.3 ABC	280.7 D	84.3 D	12.3 D	44.2 D	36.2 A	6688 D	4498 D	66.9 A
T2	**Fluroxypryre+Mcpa (strain M 50 EC) @ 750 ml ha^{-1}**	168.3 C	291.0 B	92.5 B	12.7 B	46.21 B	38.1 A	7668 B	5126 B	66.8 A
T3	**Clopyrald+ Floraxypyre + Tribenuraon (Whearstar 66 WPG) @ 500g ha^{-1}**	188.3 A	285.0 C	95.4 A	13.1A	47.56 A	39.4 A	8054 A	5575 A	69.5 A
T4	**Metsulfuran+ tribenuran (Allymax @86 SG) @35 g ha^{-1}**	186.0 AB	271.3 E	87.7 C	12.8 C	45.78 C	37.2 A	7160 C	4851 C	67.9 A
T5	**Tribenuran methyl (smbex 75 % WGD) @75 g ha^{-1}**	180.0 ABC	271.3 f	81.3 E	12.1 E	43.4 E	34.6 AB	6453 D	4062 E	72.9 A
T6	**Control**	172.0 BC	245.0 f	77.8 F	11.0 F	37.6 F	22.5 B	4525 E	2950 F	65.1 A

Hameed et al. (2019) reported that it is essential to control weeds effectively to harvest maximum possible grain yield of wheat with superior quality.

Data relating to harvest index are depicted in Table 1 and 2. It indicated that the maximum value of harvest index was observed with wheatstar plot (71.74 and 69.48 %) which was followed by a Stairn M (70.64 and 68.85 %) on both sites. Rests of the other treatments were statistically different with each other and form control. Hameed et al. (2019) reported more Harvest Index due to weeds control by weedicides.

4. Conclusion

Wheatstar and Stairn-M proved to be more efficient and productivel herbicide in controlling broad-leaved weeds in wheat. Therefore, wheat is recommended for best control of broad-leaved weeds and to get maximum yield of wheat.

Competing Interest Statement: The authors declare no conflict of interest.

List of Abbreviations: DAP, diammonium phosphate; BES, bioactive elemental sulfur; RCBD, randomized complete block design; ANOVA, analysis of variance.

Author's Contribution: Faiz Karim analyzed data, write the article, Rabia Bibi conducted the field experiment while Dr Kashif Nadeem and Dr Zakria Yousuf Hassan supervised the whole activity.

Acknowledgment: Thanks are extended thanks to workers at Adaptive Research Station, Dera Ghazi Khan.

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