Research Article

Efficacy of Newly Approved Weedicides to Control Weeds in Spring Wheat

Muhammad Zeeshan Khan[1]*, Umar Khitab Saddozai[1], Abdul Aziz Khakwani[1], Mohammad SafdarBaloch[1], Atiq Ahmad Alazai[2] and Muhammad Amjad Nadim[1]

[1]Department of Agronomy, Faculty of Agriculture, Gomal University, Dera Ismail Khan, Pakistan; [2]Department of Horticulture, Faculty of Agriculture, Gomal University, Dera Ismail Khan, Pakistan.

Abstract | To create awareness among the farmers to choose the proper weedicide among the current weedicides available in the market for controlling weeds in wheat. The present research work was conducted to evaluate the efficacy of newly approved weedicides to control weeds in spring wheat (*Triticum aestivum* L.) at Dera Ismail Khan, Pakistan, during season of 2019-2020. The experiment was laid out in randomized complete block design with split plot arrangement having 3 replications. It is concluded from the present research that for obtaining maximum wheat production, the weeds should be removed by hoeing (hand weeding) if labor is not a major problem, however among the available weedicides in the market which were used in the current research the Pallas (pyroxsulam) weedicide proved to be the excellent for obtaining higher weed control efficiency and grain yield.

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***Correspondence** | Muhammad Zeeshan Khan, Department of Agronomy, Faculty of Agriculture, Gomal University, Dera Ismail Khan, Pakistan; **Email:** zeeshan.laghari2010@gmail.com
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Introduction

Wheat is the most commonly grown and consumable food around the world as well as in Pakistan. A total of 25.195 million tons of wheat was recorded in Pakistan during 2018-2019, while area under cultivation was 8.740 million hectares. Wheat represents 8.9% of the worth in agriculture and 1.6% of Pakistan GDP (Anonymous, 2019). As weeds is common threat to crop yield and emerge in large number with every crop. According to Pakistan statistics about 40-60% of wheat yield is decreased due to weeds infestation (Abbas *et al*., 2009). Several narrow and broad leaves weeds grow in irrigated wheat crop, and they affect the crop yield and reduce its quality by using soil moisture, space, sunlight, and essential nutrients (Chhokar *et al*., 2012; Chopra *et al*., 2015). The yearly losses of wheat crop due to weeds are about 28 billion rupees in Pakistan. Weeds compete with wheat crop and reduce grain yield throughout the world. Weeds also decrease the value of produce, increase harvesting costs and surge fire threats (Ahmad *et al*., 1993). No doubt weeds are the constant threat to all crops including wheat production causing heavy yield losses (Siddiqui *et al*., 2010). Some weeds like parthenium are bad impact and threat for crops but also for the ecosystem due to their rapid spread (Bajwa *et al*., 2018). The different local, national and multinational firms are offering products for the control of various species of weeds as per recommendations including dose, efficacy, threshold level and adverse effects on wheat crop.

Although the products availability at the market has many legal prerequisites which are fulfilled as per claim by each firm. However, it remains always a great uncertainty for the farmers to choose among the several products being marketed at the same time and for the same weed specie. Majority of the growers in Pakistan are illiterate and has to rely upon the validity of recommendations claimed by the specific firm. There is no system exists for farmers to provide guidance and help selecting proper material that can save the money and time, and actually control the weeds resulting in increased yield and quality of the crop grown. Mostly methods which are used to control weeds are manually, mechanically, chemically, and biologically. However chemical weed control is considered the best in term of time saving and labor efficient method. Therefore, the weeds control by chemicals has become indispensable (Marwat *et al*., 2008). Weeds control by chemical methods is most time proficient, perfect, viable and affordable technique in reducing early weed-crop competition and increase in crop yield (Ashiq *et al*., 2007). However due to a large number of products being available in the market having different chemical composition although provide a wider choice but on the other hand puzzle the farmers in making right decision to select the proper product.

Local farmers usually have little knowledge about time of application of herbicide. Illiteracy is one of the major hurdles in acquiring this knowledge and farmers should be instructed how to calculate and normalize the herbicide dose. Using separate herbicides for broad and narrow leaves weeds is a common practice which increases the cost of production. National and multinational firms provide a single product (broad-spectrum) herbicide that can control both broad and grassy leaved weeds at a time which decrease weed density and increase the production of wheat crop (Chaudhry *et al*., 2008). Objectives of the present study were to evaluate the effects of different weedicides for the control of weeds (broad and narrow leaves) along with suppressing effect of weedicideson wheat crop.

Materials and Methods

The field experiment was carried out at the research area of Agronomy Department, Faculty of Agriculture, Gomal University, Dera Ismail Khan, (KPK) Pakistan, during season of 2019-2020. All necessary research facilities were provided at research field. Randomized Complete Block design was used with 7 treatments, replicated thrice in split plot arrangement. Sowing was done by a man driven hand drill in the mid of November. A distance of 30 cm was maintained between rows while the plant to plant distance of 10 was maintained. Net plot size was 2 m × 3 m (6 m^2) and wheat variety Khaista Gull was sown as per recommended seed rate of 100 kg ha^{-1}. Dates of application of weedicides were kept in main plot whereas various weedicides collected from different national and international firms were assigned to sub plots. Fertilizer was applied in the form of Urea, Di-Ammonium Phosphate and Sulphate of Potash as per recommended dose (150-120-90 kg NPK ha^{-1}) to all treatments equally.

Treatments main plot (Time of weedicides application)
D_1 = Weedicides application 45 days after sowing.
D_2 = Weedicides application 60 days after sowing.

Sub-plot (Different weedicides as per recommended dose, Weedy check and hand weeding)
T_1 = Atlantis Super (Mesosulfuron-Methyl, Iodosulfuron-Methyl-Sodium) @ 100 g $acre^{-1}$ (Bayer)
T_2 = Total (Sulfosulfuron, Metasulfuron-Methyl) @ 16 g $acre^{-1}$ (ICI)
T_3 = Pallas (Pyroxsulam) @ 150 mL $acre^{-1}$ (FMC)
T_4 = Broadway (Pyroxsulam, Florasulam) @ 100-110 g $acre^{-1}$ (Target *al*i Akbar group)
T_5 = Findus Xtra (Mesosulfuron, Iodosulfuron) @100 g $acre^{-1}$ (Greenlet Suncrop group)
T_6 = Weedy check
T_7 = Hand weeding (Hoeing was done throughout the growing season)

Data was recorded on the following parameters
Weed parameters: Weed density (m^{-2}), weed control efficiency (%), weed mortality (%), fresh weed biomass (g m^{-2}) and dry weed biomass (g m^{-2}).

Physiological and agronomic parameters of wheat
Chlorophyll content (μ g cm^2), Leaf area index, Crop

growth rate (g m^{-2} day^{-1}), Plant height (cm), Number of grains ($spike^{-1}$), 1000 grain weight (g), Biological yield, Grain yield (kg^{-1}), Harvest index (%).

Statistical analysis

A statistical analysis of mean data was calculated by using the computer software Statistix 8.1. The least significant difference (LSD) test at 5% probability levels will be applied for the comparison between treatments means.

Results and Discussion

Weed density (m^{-2})

Weed flora were counted before and after the weedicides application to decide which herbicide was better when compared to others to control the maximum number of narrow and broad leaves weeds. The prominent narrow and broad leaf weeds found before application of weedicides were *Avena fatua* (wild oat) and *Phalaris minor* (Dumbi sitti) grassy weeds (narrow leaf), while broad-leaved weeds were *Rumex dentatus* (bitter dock), *convolvulus arvensis* (field bindweed) and *Melilotus indica* (yellow sweet clover, common sweet clover). The data regarding newly approved weedicides shown in the Table 1. The data suggested that weedicides and interaction with application time showed significant effect on weeds density while the time of application of weedicide could not produce any significant effect on weeds population. The maximum number of weeds m^{-2} (566) was counted in weedy check plots 60 days after sowing followed by weedy check (509) with 45 days after sowing, while the lowest number of weeds i.e., 14.3 and 21.5 were noted in plots where Pallas weedicide was applied at 45 and 60 days after sowing respectively. The hand weeding plots showed no weeds at all as weeds were removed manually by hand. The other weedicides Atlantis super, Total, Broadway and Findus xtra produced statistically at par number of weeds m^{-2} 46.6, 53.8, 64.5 and 60.9 at 45 days application after sowing and also noted statistically at par number of weeds m^{-2} 53.8, 60.9, 68.1and 71.7at 60 days application after sowing as compared to hand weeding and Pallas. The Pallas weedicide gave better control of weeds among all the weedicide applied at 45 and 60 days after sowing which produced very serious depressing effect on all kinds of weeds and reduced their number per unit area. The results obtained by Asad *et al*. (2017) supported our findings who reported that the application of weedicides reduced the weeds density m^{-2} in wheat crop.

Fresh weed biomass (g m^{-2})

The data presented in Table 1, weedicides and interaction with application timings showed significant effect on fresh weeds biomass while the time of application showed non-significant effect on fresh weed biomass. The interaction of weedicide brands and their application timings showed that maximum fresh weeds biomass was noted in weedy check plot (1341 g m^{-2}) at 60 days of weedicides application after sowing, which was followed by weedy check (1016 g m^{-2}) at 45 days of weedicides application after sowing. However lowest weed fresh biomass was recorded (188.3 and 121.9 g m^{-2})

Table 1: *Efficacy of newly approved weedicides applied at different intervals on wheat crop for weed density, fresh weed biomass and dry weed biomass.*

Treatments	Weed density			Fresh weed Biomass			Dry Weed Biomass		
	45 DAS	60 DAS	Means	45 DAS	60 DAS	Means	45 DAS	60 DAS	Means
T_1 Atlantis super	46.6 cd	53.8 c	50.2 b	284.4 d	267.2 d	275.8 c	61.6 cd	55.5 d	58.6 b
T_2 Total	53.8 c	60.9 c	57.3 b	355 cd	283 d	319 bc	63.1 cd	62.7 cd	62.9 b
T_3 Pallas	14.3 e	21.5 de	17.9 c	188.3 e	121.9 e	155.1 d	33.7 e	27.6 e	30.6 b
T_4 Broadway	64.5 c	68.1 e	66.3 b	377.6 c	314.1cd	345.9b	75.3 c	61.3 cd	68.3 b
T_5 Findus xtra	60.9 c	71.7 c	66.3 b	375 c	315 cd	345 b	73.8 c	65.6 c	69.7 b
T_6 Weedy check	509 b	566 a	538 a	1016 b	1341 a	1178 a	326.3 b	376.6 a	351.4 a
T_7 Hand weeding	0 e	0 e	0.0 c	0 f	0 f	0.0 c	0 f	0 f	0.0 d
Means	107^{NS}	120		370.9^{NS}	377.6		90.5^{NS}	92.7	
$LSD_{0.05}$	Time of application = non-significant Weedicides = 18.55 Interaction = 26.29			Time of application = non-significant Weedicides = 57.81 Interaction = 148.8			Time of application = non-significant Weedicides = 11.75 Interaction = 18.28		

Means sharing different letter(s) in a column are statistically significant at 5% probability level.

in treatment where Pallas product was applied at 45 and 60 days after sowing, followed by Atlantis super and Total which produced statistically at par fresh weed biomass at 45 and 60 days of weedicidesapplication after sowing 284.4, 355, 267.2 and 283 g m^{-2}, respectively. It is further elaborated that hand weeding showed zero fresh weed biomass as the weeds were completely removed. The Pallas weedicide gave good result and reduced the weed growth and development which effected fresh weed biomass among all the weedicides at both time (45 and 60 DAS) which might be due to its active ingredient (pyroxsulam) which have strong depressing effect on weed growth in early stages as compared to other weedicide brands used in this study. Baloch *et al*. (2013) found that the application of herbicides 60 days after sowing reduced fresh weight of weeds which support our findings.

Dry weed biomass (g m^{-2})

The data displayed in the Table 1, indicated that the newly approved weedicides and interaction with time of application revealed significant effect on dry weed biomass, while time of application could not produce any significant result. The maximum dry weight of weeds was noted by weedy check (376.6 gm^{-2}) at 60 days after sowing, followed by weedy check (326.3 g m^{-2}) at 45 days after sowing. The minimum dry biomass of weeds was recorded with Pallas weedicide (33.7 and 27.6 gm^{-2}) at 45 and 60 days of application after sowing followed by Atlantis super and Total also produced at par dry weeds weight (61.6, 63.1, 55.5 and 62.7 g m^{-2}) respectively. The Pallas product created better results than other weedicides and decreased weed population and their growth and resulted in lowest dry weed biomass. Pallas weedicide not only reduced weeds population but also checked the growth of weeds very effectively. Our findings are in line with Zakariyya *et al*. (2013) who declared that the application of weedicides decreased dry weed biomass.

Weed control efficiency (%)

The data of weed control efficiency of newly approved weedicides has been shown in Table 2. The data indicated that the weedicides, time of application and interaction between two factors showed significant results. Time of weedicides application values showed maximum WCE recorded 45 days after sowing of weedicides application followed by 60 days after sowing of weedicides application. Maximum (100%) weed control efficiency was obtained in hand weeded plot due to their manual eradication. However, among the different weedicides, the Pallas showed maximum WCE (80.22%) after 45 days of weedicide application followed by Pallas after 60 days of weedicide application (73.96%). Next in order, the other weedicides Atlantis super, Total, Broadway and Findus xtra remained statistically at par showing WCE of 67.00, 60.00, 61.33 and 61.00%, respectively, at 45 days of application followed by these weedicides with WCE of 55.33, 51.00, 51.33 and 51.33%, respectively, after 60 days of weedicides application. The zero-weed control efficiency was calculated in weedy check plot (-165.24 and -304.35%) at 45 and 60 days after sowing where the weeds were allowed to compete with wheat crop unchecked. The highest weed control efficiency in Pallas (Pyroxsulam) may be due to slow and long-lasting effect of this product on weeds growth and development as a result of systemic active against growth enzymes. Our findings are supported by Sameh *et al*. (2020) noted that the highest efficiency of treatments on total weeds (broad and narrow weeds) was recorded in pyroxsulam. Hameed *et al*. (2019) who also discovered the maximum weed control efficiency in hand weeded plots (100%) as compared to other treatments.

Weed mortality (%)

The data regarding weed mortality (%) as affected by newly approved weedicides has been shown in Table 2. The data indicated that the time of application and interaction with application timings showed non-significant results while weedicides affected significantly. Highestweed mortality (100%) was recorded in hand weeding due tomanual eradication which was followed by spraying Pallas weedicides which resulted 92.61%. However, among the other weedicides the Atlantis super, Total, Broadway and Findus xtra showed at par results of weed mortality having 87.18, 86.32, 84.23 and 83.06%, respectively. The highest weed mortality was recorded in Pallas (Pyroxsulam) may be due to better control of narrow and broad leaves weeds density through long term efficacy. Hand weeding showed highest weed mortality as manual hoeing was done throughout the growing season.

Chlorophyll content (μ g cm^2)

The chlorophyll content is the parameter that indicate the photosynthetic activity and nutrition status. The data shown in Table 3, indicated that the weedicides affected the chlorophyll content significantly while

Table 2: *Efficacy of newly approved weedicides applied at different intervals on wheat crop for weed control efficiency % and weed mortality %.*

Treatments	Weed control efficiency %			Weed Mortality %		
	45 DAS	60 DAS	Means	45 DAS	60 DAS	Means
T_1 Atlantis super	67.00 bcd	55.33 d	61.17 c	87.75^{NS}	86.60	87.18 bc
T_2 Total	60.00 cd	51.00 d	55.50 c	86.89	85.74	86.32 bc
T_3 Pallas	80.22b	73.96 bc	77.09b	93.16	92.05	92.61 ab
T_4 Broadway	61.33 cd	51.33d	56.33 c	84.31	84.15	84.23 c
T_5 Findus xtra	61.00 cd	51.33d	56.17c	81.87	84.25	83.06 c
T_6 Weedy check	-165 e	-304 f	-234 d	-57.39	-76.64	-67.01 d
T_7 Hand weeding	100 a	100 a	100 a	100.00	100.00	100.00 a
Means	37.75 a	11.23 b		68.08^{NS}	65.16	
LSD $_{0.05}$	Time of application = 12.30 Weedicides = 9.71 Interaction = 16.71			Time of application = non-significant Weedicides = 7.86 Interaction = non-significant		

Means sharing different letter(s) in a column are statistically significant at 5% probability level.

Table 3: *Efficacy of newly approved weedicides applied at different intervals on wheat crop for chlorophyll content, leaf area index and crop growth rate.*

Treatments	Chlorophyll content			Leaf Area Index			Crop growth rate		
	45 DAS	60 DAS	Means	45 DAS	60 DAS	Means	45 DAS	60 DAS	Means
T_1 Atlantis super	45 ^{NS}	43	44 bcd	1.40 d	1.66 c	1.50 d	1.70^{NS}	1.76	1.73 c
T_2 Total	44	47	45 bc	1.43 d	1.62 c	1.52 cd	1.86	1.78	1.82 c
T_3 Pallas	53.70	50.06	51.88 a	1.66 c	1.79 b	1.73 b	2.76	2.56	2.66 b
T_4 Broadway	44.15	43.60	43.87cd	1.45 d	1.62 c	1.53 c	1.62	1.62	1.62 c
T_5 Findus xtra	46.66	46.23	46.45 b	1.41 d	1.63 c	1.52 cd	1.45	1.61	1.53 c
T_6 Weedy check	42.63	42.00	42.31 d	1.22 e	1.32 e	1.27 e	1.42	1.39	1.41 cd
T_7 Hand weeding	53.33	51.46	52.40 a	1.76 b	1.91 a	1.84 a	3.22	3.25	3.24 a
Means	47.06^{NS}	46.41		1.48 b	1.66 a		2 ^{NS}	1.9	
LSD $_{0.05}$	Time of application = non-significant Weedicides = 7.21 Interaction = non-significant			Time of application = 0.09 Weedicides= 0.02 Interaction = 0.09			Time of application = non-significant Weedicides = 0.43 Interaction = non-significant		

Means sharing different letter(s) in a column are statistically significant at 5% probability level.

interaction and time of application gave no variation. Among various treatment, the maximum chlorophyll content was recorded in plot of where hand weeding was performed plot and Pallas weedicide application (52.40 and 51.88 µ g cm²) followed by Findus xtra, Total, Atlantis super and Broadway 46.45, 45, 44 and 43.87 µ g cm² respectively, while minimum chlorophyll content was noted in weedy check plot (41.31µ g cm²). The results indicated that hand weeded plots and Pallas weedicide treated plots were better as compared to weedy check plots regarding chlorophyll content. The weed free plots and Pallas weedicide controlled the weeds thus reduced the crop-weed competition which resulted in better photosynthetic efficiency and gave higher chlorophyll content. Our findings are line with Bari *et al*. (2020) who found that hand weeded plots provided maximum chlorophyll content due to lower number of weeds and reduction in weed growth.

Leaf area index (LAI)

The data about the leaf area index (LAI) are revealed in Table 3, which showed that application time, weedicides and interaction with time of application was significantly affected the leaf area index (LAI). Time of weedicides application values were 1.66 recorded after 60 days of weedicides application followed by 1.48 after 45 days of weedicides application. The maximum leaf area index 1.91 recorded in hand weeded plot after 60 days of application which is followed by 1.76 LAI was also recorded in hand weeded plot after 45 days of weedicides application. These were followed by T_3 (1.79 LAI) where Pallas weedicide was applied at 60 days after sowing. Next in order the weedicides Atlantis super, Pallas, Total, Broadway and Findus xtra produced LAI of 1.60, 1.66, 1.62, 1.62 and 1.63, respectively, after 45 and 60 days of weedicide application. The minimum leaf area index was known by weedy check plot 1.22 and 1.32 due to weeds competition with crop plants 45 and 60 days after sowing. The maximum LAI in at 60 days of weedicide application after sowing with hand weeding and Pallas weedicide at 45 days of weedicide application after sowing due to similar weed control and better tolerance of wheat crop against the negative effect of weedicides due to aging of wheat crop. The interaction of 45 DAS with Pallas gave less LAI as compared to 60 DAS with Pallas might be due to tender position of wheat. The weedicides might have affected the LAI of tender wheat plant more severely as compared to 60 days. Also, weedy check plot wheat crop gave poor growth due to higher weed population. Our findings are in agreement with Noor *et al*. (2012) who stated that the lowest leaf area index in weedy check was due to higher number of weeds.

Crop growth rate (g^{-2} day^{-1})

Crop growth rate shows the rise in plant dry mass per unit area per unit time. The CGR data shown in Table 3, depicted that newly approved weedicides significantly affected CGR of wheat while their application timing and interaction could not change the CGR. The data revealed that the maximum CGR were recorded in hand weeding plot (3.24 g $^{-2}$ day^{-1}) after that T_3 where Pallas weedicide applied (2.66 g $^{-2}$ day^{-1}) as comparison to the weedy check. The next high and statistically at par CGR was recorded in Atlantis Super, Total, Broadway and Findus xtra by producing CGR of 1.73, 1.82, 1.62 and 1.53 g $^{-2}$ day^{-1}, respectively while the minimum crop growth rate was observed in weedy check plot 1.41 g $^{-2}$ day^{-1}. The weed growth in weedy check competed with wheat for longer period caused lowest crop growth rate and weedicides other than Pallas could not control weeds efficiently and weeds remained competing with crop therefore CGR of wheat was low. In the current study, the maximum CGR was noted in hand weeded plots and Pallas treatments plots that might be the result of better growth of wheat due to minimum weed competition. As in hand weeded plot almost all the weeds were removed manually, in the similar way the Pallas application controlled the maximum weed population and suppressed the growth of weeds. As a result of weeds free environment, the wheat growth increased without any competition and hindrance, hence produced better crop growth rate compared to treatments where the weed population and their growth competed with wheat crop and resulted the lesser CGR. These results are line with Abdullah *et al*. (2020) who stated that highest CGR was recorded in hand weeded plot due to minimum competition between crop plants and weeds compared with weedy check plot.

Table 4: Efficacy of newly approved weedicides applied at different intervals on wheat crop for plant height, no. of grains/spike and 1000-grain weight.

Treatments	Plant height			No. of grains / spike			1000-grain weight		
	45 DAS	60 DAS	Means	45 DAS	60 DAS	Means	45 DAS	60 DAS	Means
T_1 Atlantis super	77.66^{NS}	76.00	76.83 c	36.45^{NS}	37.15	36.83 d	50.36 c	45.30 cd	47.83cd
T_2 Total	78.66	77.66	78.16 c	36.63	39.32	36.66d	49.43c	42.40 d	45.9 cd
T_3 Pallas	86.66	86.66	86.66 b	44.64	45.16	42.00 b	58.40 b	52.43 b	55.41 b
T_4 Broadway	79.33	80.00	79.66 c	38.7	40.0	38.0 cd	51.73 c	45.50 cd	48.61 c
T_5 Findus xtra	76.33	79.33	77.83 c	40.32	42.36	39.00 c	47.03 d	43.83 d	45.43 d
T_6 Weedy check	69.66	70.33	70.00 d	32.31	32.27	30.33 e	45.46 e	36.03 e	40.75 e
T_7 Hand weeding	92.33	89.33	90.83 a	46.27	47.20	45.00 a	63.23 a	60.90 a	62.06 a
Means	80.09^{NS}	79.90		39.33^{NS}	40.51		52.23^{NS}	46.62	
LSD $_{0.05}$	Time of application = non-significant Weedicides = 3.34 Interaction = non-significant			Time of application = non-significant Weedicides= 1.36 Interaction = non-significant			Time of application = non-significant Weedicides = 3.02 Interaction = 16.1		

Means sharing different letter(s) in a column are statistically significant at 5% probability level.

Table 5: *Efficacy of newly approved weedicides applied at different intervals on wheat crop for biological yield, grain yield and harvest index %.*

Treatments	Biological yield kg ha^{-1}			Grain yield kg ha^{-1}			Harvest index %		
	45 DAS	60 DAS	Means	45 DAS	60 DAS	Means	45 DAS	60 DAS	Means
T_1 Atlantis super	7625gh	8579 efgh	8102 d	2711^{NS}	2299	2505 d	31.60^{NS}	30.22	30.91 cd
T_2 Total	8084 fgh	8651 efg	8368 d	2729	2446	2587 cd	31.51	30.28	30.89 cd
T_3 Pallas	11139 bc	10568 cd	10853b	3568	3540	3554 b	33.64	31.80	32.72 b
T_4 Broadway	9454 de	8844 ef	9149 c	2707	2862	2785 c	30.81	30.03	30.42d
T_5 Findus Xtra	8500 efgh	8723 efg	8612cd	2865	2690	2777 c	32.94	31.62	32.28 bc
T_6 Weedy Check	6473 i	7567 hi	7020 e	2259	1771	2015 e	29.87	27.48	28.68 e
T_7 Hand Weeding	12985 a	11993 ab	12489 a	4382	4278	4330 a	35.74	33.75	34.75 a
Means	9180^{NS}	9274		3017^{NS}	2856		32.30^{NS}	30.74	
LSD $_{0.05}$	Time of application = non-significant Weedicides = 757 Interaction= 1207			Time of application = non-significant Weedicides = 254 Interaction = non-significant			Time of application = non-significant Weedicides = 1.67 Interaction = non-significant		

Means sharing different letter(s) in a column are statistically significant at 5% probability level.

Plant height (cm)

The data relating to plant height as influenced by newly approved weedicides are revealed in Table 4. The data state that the weedicides affected significantly while interaction with application time and time of application produced non-significant results for plant height. Regarding different treatments, the results indicated that the tallest plants 90.83 cm were measured in hand weeded plot followed by 86.66 cm plant height measured in T_3 where Pallas weedicide applied. The other weedicides treatments T_1, T_2, T_4 and T_5 (Atlantis super, Total, Broadway and Findus xtra) produced plant height of 76.83, 78.16, 79.66 and 77.83 cm which were statistically at par weedy check. Shortest plant height of 70.00 cm was measured in weedy check plot. The tallest plant height was recorded with hand weeding and Pallas weedicide may be due to the minimum competition of wheat crop with weeds, which were either removed or suppressed by better efficacy of Pallas weedicide. While the minimum plant height in weedy check plot may be the result of heavy weeds population which suppressed the wheat crop plants, thus caused short plant height. The tallest plant height in hand weeding and Pallas weedicide plot might be due to efficient use of nutrients, light, moisture and space etc by wheat crop for the duration of vegetative growth within the time. Moreover, hoeing enhanced soil condition and made soil environment helpful for better plant growth and development. Zakariyya *et al*. (2013) supported our findings and reported that the hand weeding achieved tallest plant height as compared to weedy check.

Number of grains (spike^{-1})

The data related to number of grains per spike have been shown in the Table 4. The data indicated that weedicides caused significant effect on number of grains per spike while application time and interaction with time of application could not produce any significant effect on number of grains per spike. The highest number of grains per spike (45.00) were recorded in hand weeded plots, followed by Pallas weedicide treatment plots with (42.00) grains per spike. The other weedicides Atlantis super, Total, Broadway and Findus xtra produced statistically comparable number of grains per spike 36.83, 36.66, 38.0 and 39.00 respectively, but higher as compared to weedy check. Weedy check produced least number of grains per spike (30.33) due to high density of weeds infestation. The highest number of grains spike^{-1} in hand weeding as well as in Pallas weedicide treatment could be due to suppression of weeds and providing a greater number of available resources which delivered larger spikes. Ali *et al*. (2014) also stated that the number of grains spike^{-1} increased with decreased weed competition.

1000- grain weight (g)

The data presented in Table 4 cleared those weedicides and interaction between two factors affected 1000-grain weight significantly while time of application resulted in non-significant variation. Heaviest 1000-grain weight was recorded in hand weeded plots 63.23 and 60.90 g at 45 and 60 days after sowing followed by 58.40 and 52.43 g was observed in Pallas weedicide treated at 45 and 60

DAS. The other weedicides Atlantis super, Total, Broadway and Findus xtra showed statistically same thousand grain weight 50.36, 49.43, 51.73 and 47.03 g respectively at 45 days of weedicides application while statistically at par 1000-grain weight of 45.30, 42.40, 45.50 and 43.83 g was noted in T_1, T_2, T_4 and T_5, respectively, at 60 days of weedicides application after sowing. Lowest 1000-grain weight was recorded in weedy check 45.46 and 36.03 g at 45 and 60 days after sowing. The heaviest grain weight was recorded in hand weeding and Pallas weedicide treatments might be due to adequate amount of nutrients, proper consumption of space, light interception etc. to the wheat crop on account of lower weed population. The weedy check plots produced the lowest 1000- grain weight due to heavy competition of weeds flora with crop which reduced the 1000-grain weight. Kawa *et al*. (2016) reported that the highest thousand kernel weight (44.84 g) was observed in zero weed wheat plots with no herbicide application compared with lowest weight (35.57 g) in weedy check.

Biological yield (kg ha^{-1})

The data presented in Table 5, suggested that the biological yield was significantly affected by spraying various weedicides and interaction with application timings, while time of application results were non-significant. Hand weeded plots achieved maximum biological yield 12895 and 11993 kg ha^{-1}, respectively at 45 and 60 days after sowing. These were followed by Pallas weedicide treatment that achieved second highest biological yield of 11139 and 10568 kg ha^{-1}, respectively at 45 and 60 days of weedicide application. However minimum biological yield was noted in weedy check plot 6473 and 7567 kg ha^{-1} after 45- and 60-days sowing. The other weedicides Atlantis super, Total, Broadway and Findus xtra results of biological yield were statistically at par with weedy check. As there was no/minimum competition of weeds in hand weeding and Pallas weedicide plots, hence the wheat crop utilized all available resources e.g. space, nutrients, sunlight and water etc, hence produced the higher biological yield per unit area. These findings are supported by the Fahad *et al*. (2013) who noted that the treated plot with weedicides gave maximum biological yield as compared to weedy check.

Grain yield (kg ha^{-1})

The data illustrated in the Table 5, showed that weedicides affected significantly grain yield while time of application and interaction with application time resulted non-significant differences. The highest yield of 4330 kg ha^{-1} was noted in hand weeded plot followed by Pallas weedicide treatment with 3554 kg ha^{-1}. The weedicides Total, Broadway and Findus xtra stood second in producing statistically similar grain yield of 2587, 2785, and 2777 kg ha^{-1}, respectively, while lowest grain yield of 2015 kg ha^{-1} was harvested from weedy check followed by treatment sprayed with Atlantis super by giving grain yield of 2505 kg ha^{-1}. No doubt the maximum grain yield was obtained by hand weeding due to complete weed removal and there was no competition of weeds with wheat crop. Among weedicide brands Pallas was next to hand weeding while other weedicide brands produced almost at par yield. It indicated that Pallas gave better weed control efficiency and killed or suppressed the weeds growth of narrow and broad leaf weeds resulting in minimum competition thus produced higher grain yield. The lowest grain yield in treatment weedy check may be due to unchecked weed population and growth, which enhanced the competition with wheat regarding space, nutrients, light and water, thus all the growth contributing parameters were negatively affected and finally resulted in lowest grain yield. Our research results findings are supported by Hashim *et al*. (2002) who stated that maximum grain production was produced through treatment of weedicides. Our findings also are line with Arif *et al*. (2015) who reported that the highest grain yield of wheat was noted in all treatments as compared weedy check.

Harvest index (%)

Harvest index (HI) is the proportion of grain production to biomass of a crop that indicates the effectiveness of plant to convert its photosynthates into commercial yield. The data pertaining to harvest index is given in Table 5, showed that the newly approved weedicides significantly affected harvest index while interaction with application timings and time of application results were found non-significant. The maximum harvest index was noted in hand weeding 34.75% followed by Pallas and Findus xtra weedicide treatments by producing HI of 32.72 and 32.28%, respectively. The other weedicides Atlantis Super, Total and Broadway produce statistically similar harvest index 30.91, 30.89 and 30.42%, respectively. The lowest harvest index 28.68% was recorded in weedy check plot. In this research, maximum harvest index recorded in hand weeded plots and Pallas weedicide treatment was attributed to better weed management. The least harvest index was noted in weedy check plot due to low grain yield as compared to biomass production causing serious effect of weeds competition with wheat crop. These findings are supported by Rab *et al*. (2016) who stated that the hand weeded, and herbicide treated plots gave more harvest index as compared to weedy check.

Conclusions and Recommendations

Based on current research study, our findings are leading to the following conclusions. Hand weeding is the most efficient method for weed management if the wheat crop is planted up on small area and availability of labor at low-cost but on large scale the chemical weed control is practicable. All the weedicides gave more effective control of weeds as compared to weedy check. Comparing among the weedicides, the Pallas (Pyroxsulam) produced better weed control efficiency (broad and narrow) when applied at 45 DAS followed by 60 DAS. Atlantis super (Mesosulfuron-Methyl, Iodosulfuron-Methyl-Sodium) proved to be the second effective weedicide regarding weed control efficiency after 45 DAS. It is also observed that Atlantis Super weedicide had suppressing effect on the growth of wheat as well. Among all the treatments, the maximum grain production of wheat 4330 kg ha^{-1} was recorded in hand weeding while among the weedicides the highest gain yield of 3554 kg ha^{-1} was harvested by Pallas followed by Broadway (2785 kg ha^{-1}), Findus xtra (2777 kg ha^{-1}), Total (2587 kg ha^{-1}) and Atlantis Super (2505 kg ha^{-1}). However, the weedy check gave the lowest grain yield of 2015 kg ha^{-1}.

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Novelty Statement

The current study is designed to compare the newly approved available weedicides of various firms and analyze their effectiveness and economics with higher yield of wheat and to enhance capacity of growers to choose the best product.

Author's Contribution

Muhammad Zeeshan Khan: Researcher/ Carried out complete research trail.
Umar Khitab Saddozai: Major supervisor.
Abdul Aziz Khakwani: Major member of the research committee.
Mohammad Safdar Baloch: Editing in overall write up.
Atiq Ahmad Alazai: Minor member of the research committee.
Muhammad Amjad Nadim: Statistical analysis.

Conflict of interest

The authors have declared no conflict of interest.

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