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Article

APPLICATION OF VARIOUS HERBICIDES ON CONTROLLING LARGE AND NARROW LEAF WEEDS AND THEIR EFFECTS ON PHYSIOLOGICAL AND AGRONOMIC TRAITS OF WHEAT

Aplicação de Diversos Herbicidas no Controle de Plantas Daninhas de Folhas Grandes e Estreitas e seus Efeitos nas Características Fisiológicas e Agronômicas do Trigo

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ABSTRACT - In order to examine application of various herbicides for controlling weeds in wheat crop, a field trial was conducted at the Agronomic Research Area, Faculty of Agriculture, Gomal University, Dera Ismail Khan, Khyber Pakhtunkhwa (KPK) during the year 2015-2016. The experiment was laid out in a randomized complete block design (RCBD) with split-plot arrangements having three replications. The main plot was comprised application time of herbicides while the use of herbicides was assigned to sub-plots. The data revealed that most of the weed parameters, physiological traits and agronomic attributes of crop plants were significantly affected by weed management practices including the use of herbicides at different time intervals over the weedy check. Hand weeding technique excelled all other weed management practices in almost all the parameters studied. This technique was found to be the most effective treatment against all prevailing weeds and obtained the highest grain yield of wheat under climatic conditions of Dera Ismail Khan.

Keywords: weeds, herbicides, practices, control.

RESUMO - A fim de examinar a aplicação de vários herbicidas para o controle de plantas daninhas na cultura do trigo, um estudo de campo foi realizado na Área de Pesquisa Agronômica da Faculdade de Agricultura da Universidade Gomal, Dera Ismail Khan, Khyber Pakhtunkhwa (KPK), durante o ano 2015-2016. O experimento foi realizado em delineamento de blocos completos casualizados (RCBD) com parcelas subdivididas, com três repetições. A parcela principal foi composta pelo tempo de aplicação dos herbicidas, enquanto o uso de herbicidas foi atribuído às subparcelas. Os dados revelaram que a maioria dos parâmetros de plantas daninhas, características fisiológicas e atributos agronômicos das plantas cultivadas foram significativamente afetados pelas práticas de manejo das plantas daninhas, incluindo o uso de herbicidas em diferentes intervalos de tempo durante o teste de plantas daninhas. A técnica de capina manual superou todas as demais práticas de manejo de plantas daninhas em quase todos os parâmetros estudados. Esta técnica foi considerada o tratamento mais eficaz contra todas as plantas daninhas predominantes e obteve o maior rendimento de grãos de trigo sob condições climáticas de Dera Ismail Khan.

Palavras-chave: planta daninha, herbicidas, práticas, controle.

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is the staple food crop in Pakistan. It dominates all agronomic crops with respect to area and production and contributes 10.3% to value added in agriculture and 2.2% to gross domestic product (Pakistan, 2014). Wheat is annually cultivated on an area of 9.03 million hectares (MH) with total production of 25.3 million tons in Pakistan. In Khyber Pakhtunkhwa, wheat is grown on 313 thousands hectares with an average yield of 1,860 kg ha^{-1} (Pakistan, 2014). Its national average yield per unit area is, however, low in the country due to a number of biotic and a biotic factors including low yielding varieties, meager levels of inputs coupled with heavy weeds infestation (Baloch et al., 2013; Mahmood et al., 2017; Iqbal et al., 2018).

Weeds are the undesirable plants, which compete with crop plants for light, space, nutrients and affect quality of seed through allelopathy and contamination etc (Shah et al., 2016; Iqbal et al., 2017). High weed intensity and more competition time with crop plants cause more reduction in crop yield (Dalley et al., 2006; Chaudhry et al., 2008a). Weed competition at early growth stages of crop causes more reduction in growth and yield (Reddy, 2004). Annual losses to wheat crop due to weed infestation are reported to be in billions, these enormous losses warrant an efficient control of weeds for lucrative economic returns. Severe weed infestation is one of the major causes of low wheat yield in the country. It is estimated that about 20 to 40% wheat yield losses are due to weeds. After sowing, the critical weed competition period is 30-60 days, and after that time, it is no economic benefit to eradicate weeds from wheat crop (Ahmad and Shaikh, 2003).

Weeds control is a key factor in crop yield enhancement. Weeds are obscured enemies of wheat and cause massive losses to crop yields (Atta and Khaliq, 2002). Hamid et al. (1998) reported that weed competition in wheat crop reduce yield by 42% and 56%. In contrast, a significant increase in wheat yield is reported by using different herbicides as compare to weedy check (Tariful et al., 1998; Chaudhry et al., 2008b).

There are several ways to control weeds including cultural, chemical, biological and manual weeding. Each method has a significant role in controlling weeds; however, some of the control measures are out of reach of poor farmers in developing countries. Excessive tillage and hand weeding can effectively control weeds but the recent energy crises and high labour cost in our country may affect farmers' interest and profitability in adopting physical weed control technique. Under these circumstances, chemical weed control appears to be most viable and economical method of weed control (Dalley et al., 2006). Through stimulation of protein or RNA biosynthesis, the use of herbicides causes a plant death (Rao, 2000).

Since weed problem in wheat crop is increasing considerably with the addition of newly emerged weeds, it was therefore felt imperative to find out the exact time of competition of weeds with wheat crop and their well-timed management through herbicides application at various growth intervals under the climatic conditions of Dera Ismail Khan.

MATERIALS AND METHODS

The experiment was conducted at the Agronomic Research Area of Gomal University, Dera Ismail Khan, Khyber Pakhtunkhwa during the year 2015-2016. The experiment was laid out in a randomized complete block design with split-plot arrangement having three replications. The net plot size was 1.8 m x 3 m (5.4 m^2). Wheat variety Gomal-8 was sown on a well prepared seedbed with single row hand drill using 100 kg seed ha^{-1}. Fertilizers were applied Nitrogen (N), phosphorus (P) and potash (K). NPK were applied in form of urea, Single Super Phosphate, Murate of Potash at the rate of 150:120:90 kg ha^{-1} respectively. Full dose of P, K and half dose of N were applied at seedbed preparation while the remaining half N was applied at first irrigation. According to local standards, all cultural practices were followed. The detail of treatments is given as under:

Main plot	
	Time of application
	M1= 30 days after sowing
	M2= 60 days after sowing
	Sub-plots
	Herbicides
1	For broad leaf weeds
	Wheat Star (Tribenuron+Fluraxypyr+Clorophyralid)
	Bromax (Bromoxinal+MCPA)
	Selector (Bromoxinal+MCPA)
	Staraine M (Fluraxypyr)
	Buctril Super (Bromoxinal+MCPA)
	Alymax (Mesosulfuron+Iodosulfuran)
2	For narrow leaf weeds
	Kill Fop (Clodinafop)
	Clincher (Bromoxinal+MCPA)
	Axial (Propinocarb)
	Plate Form (Clodinafop)
	Puma Super (Fenoxaprop P Ethyl)
	Pujjing (Fenoxaprop P Ethyl)
3	For both broad and narrow leaf weeds
	Atlantus (Tribenuron+Metsulfuron)
	Hand Weeding
	Control (Weedy check)

Data on chlorophyll content (µg cm^{-2}) at 45 and 90 days after sowing (DAS), leaf area index at 45 and 90 DAS, weed density (m^{-2}) and dry weed biomass (g m^{-2}) at 30 and 60 DAS, number of tillers (m^{-2}), spike length (cm), number of grains ($spike^{-1}$), 1000-grain weight (g) and grain yield (ton ha^{-1}) were analyzed statistically by using analysis of variance techniques (Steel et al., 1997) and Duncan multiple range test was applied to see the level of significance, if any, among treatments with the help of "Statistics" software.

RESULTS AND DISCUSSION

Chlorophyll content (µg cm^{-2}) at 45 and 90 DAS

Chlorophyll content is always a good indicator of photosynthetic activity and nutritional state. It provides valuable information about the physiological status of crops. The data presented in (Table 1) showed that the use of various herbicides at 45 DAS significantly affected chlorophyll content of wheat crop. Among various treatments, the maximum chlorophyll content at 45 DAS (48.983 µg cm^{-2}) was recorded where hand weeding was done. It was, however, statistically at par with all other treatments except the untreated control which had 39.583 µg cm^{-2} chlorophyll content. The minimum chlorophyll content (39.583 µg cm^{-2}) was noted in weedy check. The interaction of time of application and the herbicidal effect was found non-significant statistically. The maximum chlorophyll content noted in hand weeded plots was probably due to lower weed population and suppression of weed growth, as they were uprooted to a large extent and later suppressed by the crop (Baloch et al., 2005). The reverse was true as in case of weedy control where no weeding was done.

The data given in (Table 1) at 90 DAS revealed that the application of herbicides considerably affected chlorophyll content of wheat. As far as the use of different herbicides is concerned, the maximum chlorophyll content (52.750 µg cm^{-2}) was noted in hand weeded plots. It was, however, statistically at par with all other treatments except the untreated control which had 44.683 µg cm^{-2} chlorophyll content at 90 DAS. The interaction of time of application and use of various herbicides was found non-significant statistically. The minimum chlorophyll content in untreated control was probably due to the higher weed influx (30 and 60 days after herbicides application) and their keen competition for available resources (light, water, space, nutrients, etc.) which eventually restricted crop plants to produce higher chlorophyll content as weed competition at early growth stages of crop causes more reduction in growth and yield (Reddy, 2004).

Table 1 - Chlorophyll content (µg cm^{-2}) at 45 and 90 days after sowing (DAS) as affected by time of different herbicides application in wheat

Herbicide name	45 DAS			90 DAS		
	Application time		Mean	Application time		Mean
	30 DAS	60 DAS		30 DAS	60 DAS	
H_1 = Plate Form (Clodinafop)	45.500 ^{NS}	48.800	47.150 a	53.233 ^{NS}	49.100	51.167 ab
H_2 = Killfop (Clodinafop)	47.700	48.133	47.917 a	53.267	48.637	50.950 ab
H_3 = Wheat Star (Tribenuron + Fluraxypyr + Clorophyralid)	49.167	47.867	48.517 a	51.133	47.333	49.233 ab
H_4 = Clincher (Bromoxinal + MCPA)	48.167	47.567	47.867 a	49.867	47.667	48.767 ab
H_5 = Bromax (Bromoxinal + MCPA)	49.067	47.967	48.517 a	52.567	48.000	50.283 ab
H_6 = Pujjing (Fenoxaprop-p-ethyl)	47.633	47.567	47.600 a	53.300	52.167	52.733 a
H_7 = Selector (Bromoxinal + MCPA)	47.500	44.033	45.767 ab	53.800	49.067	51.433 ab
H_8 = Staraine M (Fluraxypyr)	45.800	44.500	45.150 ab	51.700	54.600	53.150 a
H_9 = Axial (Propinocarb)	47.500	47.767	47.633 a	50.300	54.467	52.383 a
H_{10} = Buctril Super (Bromoxinal + MCPA)	46.867	42.900	44.883 ab	51.300	51.500	51.400 ab
H_{11} = Puma Super (Fenoxaprop-p-ethyl)	44.333	47.533	45.933 ab	53.167	51.600	52.383 a
H_{12} = Atlantis (Tribenuron + Metsulfuron)	46.067	47.533	46.800 a	50.533	49.767	50.150 ab
H_{13} = Alymax (Mesosulfuron + Iodosulfuran)	42.000	45.633	43.817 ab	51.033	49.567	50.300 ab
H_{14} = Hand Weeding	48.400	49.567	48.983 a	53.033	52.467	52.750 a
H_{15} = Control (no weeding)	39.400	39.767	39.583 b	44.400	44.967	44.683 b
Mean	46.340 ^{NS}	46.476		51.509 ^{NS}	50.060	

$LSD_{0.05}$ (Herbicides) = 6.879, 7.373 at 45 and 90 DAS respectively. Different letters are shown statistically significant at 5% probability. ^{NS} Non-significant.

Leaf area index at 45 and 90 DAS

Leaf area and the associated indices are among the important growth parameters being suggestive of higher photosynthetic efficiency of crop and eventually a greater yield (Channappagoudar et al., 2013). The data shown in (Table 2) at 45 DAS revealed that there was no significant effect of time of application of herbicides and their individual and interactive effects on leaf area index. Hand weeded plots however produced higher leaf area index (0.5867) than all other treatments mainly due to production of higher chlorophyll content throughout plant growth period. This shows that treatments effectively suppressing the weeds could improve the wheat physiological attributes due to improved availability of minerals, water and light, which otherwise would be utilized by the weeds. The lower leaf area index in untreated control was due to severe weed-crop competition in these plots that led to inadequate supply of moisture and nutrients to the crop plants.

Table 2 - Leaf area index at 45 and 90 DAS as affected by time of different herbicides application in wheat

Herbicide name	Application time		Mean	Application time		Mean
	30 DAS	60 DAS		30 DAS	60 DAS	
H_1 = Plate Form (Clodinafop)	0.3933 ^{NS}	0.3633	0.3783 ^{NS}	1.0133 ^{NS}	0.7533	0.8833 ^{NS}
H_2 = Killfop (Clodinafop)	0.4633	0.4967	0.4800	1.0933	1.0933	1.0933
H_3 = Wheat Star (Tribenuron + Fluraxypyr + Clorophyralid)	0.3633	0.5000	0.4317	0.9433	1.0867	1.0150
H_4 = Clincher (Bromoxinal + MCPA)	0.6800	0.4500	0.5650	1.1533	0.8500	1.0017
H_5 = Bromax (Bromoxinal + MCPA)	0.5600	0.3600	0.4600	1.0900	0.9633	1.0267
H_6 = Pujjing (Fenoxaprop-p-ethyl)	0.5000	0.4867	0.4933	0.9333	1.2100	1.0717
H_7 = Selector (Bromoxinal + MCPA)	0.5500	0.3433	0.4467	1.1167	0.8400	0.9783
H_8 = Staraine M (Fluraxypyr)	0.4900	0.4400	0.4650	0.9233	0.9233	0.9600
H_9 = Axial (Propinocarb)	0.4667	0.2933	0.3800	0.7967	0.9567	0.8767
H_{10} = Buctril Super (Bromoxinal + MCPA)	0.5500	0.3633	0.4567	1.2300	0.8600	1.0450
H_{11} = Puma Super (Fenoxaprop-p-ethyl)	0.3933	0.3833	0.3883	0.9933	0.9167	0.9550
H_{12} = Atlantis (Tribenuron + Metsulfuron)	0.5267	0.2800	0.4033	1.2600	0.6100	0.9350
H_{13} = Alymax (Mesosulfuron + Iodosulfuran)	0.5433	0.5000	0.5217	1.2700	0.9300	1.1000
H_{14} = Hand Weeding	0.6033	0.5700	0.5867	1.2933	1.2467	1.2700
H_{15} = Control (no weeding)	0.3700	0.3267	0.3483	0.9033	0.7967	0.8500
Mean	0.0490 ^{NS}	0.4100		1.0724 a	0.9358 b	

$LSD_{0.05}$ (Application time) at 90 DAS = 0.0742. Different letters are shown statistically significant at 5% probability. ^{NS} Non-significant.

The data presented in (Table 2) showed that the use of various herbicides has no significant effect on leaf area index. However, among various weed management practices, the highest leaf area index (1.2700) at 90 DAS was noted in hand weeded plots while the lowest (0.8500) in untreated control. This is because in control no weeding was done and the growth of weeds went unchecked therefore they had the maximum opportunity to thrive in the highest number because of the absence of any of the competing agents and utilization of all the resources up to the optimum level. In the present study, a comparable leaf area index was noted in herbicides treatments including Plate Form and Axial with that of untreated control. It might be due to the reason that the use of herbicides sometime causes to reduce physiological activities of crop plants because of their phytotoxic effects on crop plants, which inhibits photosynthesis due to the reduction in photosynthetic pigments (Khan et al., 2006; Hana et al., 2015). As far as the effect of time of herbicides application is concerned, significantly higher leaf area index (1.0724 m^{-2}) was noted at 30 days after herbicides application than that (0.9358 m^{-2}) recorded at 60 days after herbicides application. It shows that weed control at proper time provided favourable environment for the crop growth and development. The herbicidal affect and the interaction of time of application of herbicides were found non-significant statistically.

Weed density (m^{-2}) at 30 and 60 DAS

The data given in (Table 3) revealed that weed density was non-significantly affected by various herbicides and their time of application. However, the interaction of these two factors was found significant statistically. Among various treatments, the maximum weed density (113.33 m^{-2}) was recorded in untreated control whereas hand weeded plots had minimum weed density (34.00 m^{-2}) at 30 DAS. The time of application of herbicides and the herbicidal effect was found significant statistically. Atlantis treated plots had maximum (177.33 m^{-2}) while hand weeded plots had minimum (33.00 m^{-2}) weed density 30 days after herbicides application. The lowest weed population from hand weeding might be related to suppression of weed growth, as they were uprooted to a large extent and later suppressed by the crop (Baloch et al., 2005). The minimum weed count at 30 days after herbicide application might be due to the reason that all germinated weeds were uprooted before their critical competition with the crop plants for nutrients, light, water etc. Similarly, the weed density in herbicides treated plots was considerably lower than the untreated control. It was due to the effect of chemicals which when applied at early stage of weeds germination killed almost all the weeds. Hassan et al. (2003) reported reduced number of weeds in wheat by using various herbicides. This reduction in number of weeds in herbicidal treatments was attributed to the phytotoxic effect of herbicides on weeds.

Table 3 - Weed density (m^{-2}) at 30 and 60 days after sowing as affected by time of different herbicides application in wheat

Herbicide mame	Application time		Mean	Application time		Mean
	30 DAS	60 DAS		30 DAS	60 DAS	
H_1 = Plate Form (Clodinafop)	62.67 abc	54.67 abc	58.67 ^{NS}	16.33 a-d	24.00 a-d	19.667 a-e
H_2 = Killfop (Clodinafop)	33.33 c	48.00 abc	40.67	37.33 ab	35.66 abc	36.500 a
H_3 = Wheat Star (Tribenuron + Fluraxypyr + Clorophyralid)	84.00 abc	37.33 abc	60.67	25.33 a-d	18.33 a-d	21.833 a-e
H_4 = Clincher (Bromoxinal + MCPA)	102.67 abc	37.33 abc	70.00	12.00 bcd	10.66 bcd	11.333 b-e
H_5 = Bromax (Bromoxinal + MCPA)	41.33 abc	64.00 abc	52.67	9.33 bcd	20.00 a-d	14.667 b-e
H_6 = Pujjing (Fenoxaprop-p-ethyl)	56.00 abc	37.33 abc	46.67	37.33 ab	15.00 a-d	26.167 abc
H_7 = Selector (Bromoxinal + MCPA)	161.33 ab	61.33 abc	111.33	18.66 a-d	13.66 a-d	16.167 a-e
H_8 = Staraine M (Fluraxypyr)	73.33 abc	45.33 abc	59.33	30.66 a-d	12.66 bcd	21.667 a-e
H_9 = Axial (Propinocarb)	162.67 ab	46.67 abc	104.67	21.33 a-d	12.33 bcd	16.83 a-e
H_{10} = Buctril Super (Bromoxinal + MCPA)	105.33 abc	54.67 abc	80.00	28.00 a-d	18.00 a-d	23.000 a-d
H_{11} = Puma Super (Fenoxaprop-p-ethyl)	69.33 abc	46.67 abc	58.00	30.66 a-d	28.00 a-d	29.333 ab
H_{12} = Atlantis (Tribenuron + Metsulfuron)	177.33 a	44.00 abc	110.67	6.66 bcd	5.66 bcd	6.167 cde
H_{13} = Alymax (Mesosulfuron + Iodosulfuran)	78.67 abc	45.33 abc	62.00	5.33 bcd	4.66 cd	5.000 de
H_{14} = Hand Weeding	30.67 c	37.33 abc	34.00	1.000 d	2.66 d	1.83 e
H_{15} = Control (no weeding)	162.67 ab	64.00 abc	113.33	46.66 a	35.66 abc	41.16 a
Mean	86.75 ^{NS}	48.26		22.778 ^{NS}	15.778	

$LSD_{0.05}$ (Interaction) = 127.34, 32.525 at 30 and 60 DAS respectively. Different letters are shown statistically significant at 5% probability. ^{NS} Non-significant.

The data given in (Table 3) indicated that weed density was significantly higher (41.16 m^{-2}) in untreated control whereas lower (1.83 m^{-2}) was recorded in hand weeded plots at 60 DAS. However, the time of application of herbicides was found non-significant statistically. The interaction of herbicides and time of herbicides application revealed that maximum weed density (46.66 m^{-2}) was found in control plots at 30 days after herbicides application while minimum weed density (2.66 m^{-2}) was noted in hand weeded plots at 60 days after herbicides application. The weed density was lower in hand weeded plots due to lower weed-crop competition that resulted in higher absorption of nutrients and sufficient interception of sunlight as well as air. In general, weed density was lower in herbicides treated plots than the weedy check on account of adequate weed management at proper time.

Dry weed biomass (g m^{-2}) at 30 and 60 DAS

The data given in (Table 4) revealed that the time of application and the herbicidal activity had no significant effects on dry weed biomass at 30 DAS. Among treatments, maximum dry weed biomass (24.866 g m^{-2}) was noted in untreated control as compare to minimum (10.200 g m^{-2}) dry weed biomass recorded in hand weeded plot. Similarly, significantly higher dry weed biomass (23.369 g m^{-2}) was noted at 60 days after herbicides application than that recorded at 30 days after herbicides application. The interaction of time of application and the herbicidal activity showed that maximum dry weed biomass (40.933 g m^{-2}) was produced in untreated control at 60 days after herbicides application whereas Killfop, Bromax and hand weeded plots produced minimum and equal dry weed biomass (5.200 g m^{-2}) at 30 days after herbicides application. The minimum dry weed biomass especially in hand weeded plots was probably due to low weed density and good suppression of weeds. Arif et al. (2004) also reported that hand weeding and herbicidal treatments suppressed the weed biomass considerably than the untreated control.

Table 4 - Dry weed biomass (g m^{-2}) at 30 and 60 days after sowing as affected by time of different herbicides application in wheat

Herbicide name	Application time		Mean	Application time		Mean
	30 DAS	60 DAS		30 DAS	60 DAS	
H_1 = Plate Form (Clodinafop)	5.400 bc	17.467 abc	11.433 ^{NS}	24.07 c	58.00 bc	41.033 abc
H_2 = Killfop (Clodinafop)	5.200 c	28.667 abc	16.933	28.33 bc	62.83 bc	45.58 abc
H_3 = Wheat Star (Tribenuron + Fluraxypyr + Clorophyralid)	6.800 bc	21.067 abc	13.933	12.53 c	69.43 abc	40.983 abc
H_4 = Clincher (Bromoxinal + MCPA)	7.333 bc	16.400 abc	11.867	7.00 c	25.13 c	16.067 c
H_5 = Bromax (Bromoxinal + MCPA)	5.200 c	37.067 ab	21.133	8.00 c	30.87 bc	19.433 bc
H_6 = Pujjing (Fenoxaprop-p-ethyl)	5.867 bc	20.933 abc	13.400	20.13c	79.47 abc	49.800 abc
H_7 = Selector (Bromoxinal + MCPA)	8.800 bc	20.267 abc	14.533	7.47 c	29.43 bc	18.450 bc
H_8 = Staraine M (Fluraxypyr)	8.667 bc	15.200 abc	11.933	17.07 c	36.80 bc	26.933 bc
H_9 = Axial (Propinocarb)	6.933 bc	22.800 abc	14.866	19.20 c	71.10 abc	45.15 abc
H_{10} = Buctril Super (Bromoxinal + MCPA)	8.000 bc	22.667 abc	15.333	13.60 c	35.80 bc	24.700 bc
H_{11} = Puma Super (Fenoxaprop-p-ethyl)	6.533 bc	26.533 abc	16.533	26.80 c	114.26 ab	70.517 ab
H_{12} = Atlantis (Tribenuron + Metsulfuron)	8.267 bc	15.733 abc	12.000	20.00 c	66.27 bc	43.133 abc
H_{13} = Alymax (Mesosulfuron + Iodosulfuran)	6.000 bc	19.067 abc	12.533	8.33 c	25.20 c	16.765 c
H_{14} = Hand Weeding	5.200 c	15.200 abc	10.200	6.13 c	5.87 c	6.00 c
H_{15} = Control (no weeding)	8.800 bc	40.933 a	24.866	30.00 bc	152.80 a	91.40 a
Mean	6.982 b	23.369 a		16.644 b	57.549 a	

$LSD_{0.05}$ (Application time) = 8.066, 23.653 at 30 and 60 DAS respectively, $LSD_{0.05}$ (Interaction) = 27.123, 85.182 at 30 and 60 DAS respectively. Different letters are shown statistically significant at 5% probability. ^{NS} Non-significant.

The data presented in (Table 4) revealed that the time of herbicides application, herbicidal effects as well as their interaction significantly affected dry weed biomass at 60 DAS. Among various treatments, hand weeded plots produced significantly lower (6.00 g m^{-2}) dry weed biomass as compare to untreated control. It was, however, at par statistically with herbicidal treatments Alymax (16.765 g m^{-2}) and Clincher (16.067 g m^{-2}). As far as the time of herbicides application is concerned, dry weed biomass was significantly higher (57.549 g m^{-2}) at 60 days after herbicides application than that recorded at 30 days after herbicides application. The interaction of time of herbicides application and the herbicidal effects showed the highest dry weed biomass

(152.80 g m^{-2}) in weedy check while hand weeded plots produced the lowest (5.87 g m^{-2}) dry weed biomass both at 60 days after herbicides application. The lowest weed density in hand weeded plots was probably due to suppression of weeds to the extent where they could not emerge and compete with crop plants for resources during their later growth stages. Similarly, the comparable response of weeds to herbicides Alymax and Clincher application revealed that these herbicides were more effective in lowering dry weed biomass as compare to the other chemicals and the untreated control. Pandey et al. (2002) stated that weed population and weed dry weight were significantly lower under weed control treatments than the weedy control.

Number of tillers (m^{-2})

The data given in (Table 5) revealed that the use of different herbicides significantly affected number of tillers of wheat crop. Among different treatments, the maximum number of tillers (324.00 m^{-2}) was recorded where hand weeding was done. It was, however, statistically at par with all other treatments except the plots treated with Plate Form, Axial and weedy check which had 216.00, 198.67 and 180.33 number of tillers (m^{-2}) respectively. The time of application of herbicides and the interaction of time of application and the herbicidal effects was found non-significant statistically. The highest number of tillers in hand-weeding plot might be due to less number of weeds and availability of sufficient amount of nutrients to crop plants. Hussain et al. (2003) and Alvi et al. (2004) reported an increase in number of tillers due to better weed control and elimination of weed crop competition for nutrients, moisture and light and better utilization of available resources by the crop.

Table 5 - Number of tillers (m^{-2}) as affected by time of different herbicides application in wheat

Herbicide name	Application time		Mean
	30 DAS	60 DAS	
H_1 = Plate Form (Clodinafop)	228.67 ^{NS}	203.33	216.00 b
H_2 = Killfop (Clodinafop)	258.00	272.33	265.17ab
H_3 = Wheat Star (Tribenuron + Fluraxypyr + Clorophyralid)	239.33	251.67	245.50 ab
H_4 = Clincher (Bromoxinal + MCPA)	293.33	236.67	265.00 ab
H_5 = Bromax (Bromoxinal + MCPA)	258.33	233.67	246.00 ab
H_6 = Pujjing (Fenoxaprop-p-ethyl)	247.33	268.67	258.00 ab
H_7 = Selector (Bromoxinal + MCPA)	283.00	196.67	239.83 ab
H_8 = Staraine M (Fluraxypyr)	251.37	227.00	239.17 ab
H_9 = Axial (Propinocarb)	204.67	192.67	198.67 b
H_{10} = Buctril Super (Bromoxinal + MCPA)	268.00	218.33	243.17 ab
H_{11} = Puma Super (Fenoxaprop-p-ethyl)	238.00	220.33	229.17 ab
H_{12} = Atlantis (Tribenuron + Metsulfuron)	297.00	227.67	262.33 ab
H_{13} = Alymax (Mesosulfuron + Iodosulfuran)	296.00	245.00	270.50 ab
H_{14} = Hand Weeding	336.67	311.33	324.00 a
H_{15} = Control (no weeding)	199.67	161.00	180.33 bc
Mean	259.96 ^{NS}	231.09	

$LSD_{0.05}$ (Herbicides) = 96.736. Different letters are shown statistically significant at 5% probability. ^{NS} Non-significant.

Spike length (cm)

The data presented in a (Table 6) exhibited that the time of application of herbicides, herbicidal effect and their interaction was found non-significant statistically. Herbicide Plate Form had the maximum spike length (9.4717 cm) closely followed by Killfop (9.4283 cm) and hand weeding (9.3600 cm). Similarly, the maximum spike length (9.0171 cm) was noted at 60 days after herbicides application while minimum (8.8409 cm) spike length was measured at 30 days after herbicides application. The interaction revealed that the highest spike length (9.7367 cm) was calculated in Killfop treated plot at 60 days after herbicides application while the lowest spike length (8.3500 cm) was noted in weedy check at 30 days after herbicides application. Herbicides

Table 6 - Spike length (cm) as affected by time of different herbicides application in wheat

Herbicide name	Application time		Mean
	30 DAS	60 DAS	
H_1 = Plate Form (Clodinafop)	9.2300 ^{NS}	9.7133	9.4717 ^{NS}
H_2 = Killfop (Clodinafop)	9.1200	9.7367	9.4283
H_3 = Wheat Star (Tribenuron + Fluraxypyr + Clorophyralid)	8.9233	9.4100	9.1667
H_4 = Clincher (Bromoxinal + MCPA)	8.8067	8.8333	8.8200
H_5 = Bromax (Bromoxinal + MCPA)	9.3333	9.1500	9.2416
H_6 = Pujjing (Fenoxaprop-p-ethyl)	8.5333	8.7600	8.6467
H_7 = Selector (Bromoxinal + MCPA)	8.5700	8.5533	8.5617
H_8 = Staraine M (Fluraxypyr)	8.7967	8.9267	8.8617
H_9 = Axial (Propinocarb)	8.5833	8.8833	8.7333
H_{10} = Buctril Super (Bromoxinal + MCPA)	8.5000	8.6500	8.5750
H_{11} = Puma Super (Fenoxaprop-p-ethyl)	8.9500	8.7033	8.8267
H_{12} = Atlantis (Tribenuron + Metsulfuron)	9.1533	9.0667	9.1100
H_{13} = Alymax (Mesosulfuron + Iodosulfuran)	8.6033	9.0233	8.8133
H_{14} = Hand Weeding	9.1600	9.5600	9.3600
H_{15} = Control (no weeding)	8.3500	8.5700	8.4600
Mean	8.8409 ^{NS}	9.0171	

^{NS} Non-significant.

application enhanced spike length due to timely and efficiently weeds management which resulted in higher nutrients availability to crop plants. These findings are supported by Zakariyya et al. (2013) who studied the integrated weed management strategies and reported that herbicides significantly affected growth and yield attributes including spike length of wheat.

Number of grains (spike^{-1})

The data pertaining to number of grains are presented in (Table 7). The data revealed that the time of application of herbicides, herbicidal effect and their interaction had no significant effect on number of grains per spike of wheat. Among treatments, maximum number of grains (43.933) per spike was counted in hand-weeding plots whereas weedy check produced minimum (37.966) number of grains. Similarly, the number of grains per spike was maximum (41.213) at 30 days after herbicides application as compare to 60 days after herbicides application. As far as the interaction is concerned, the maximum numbers of grains (44.067 spike^{-1}) was noted by the application of Wheat star herbicide while the minimum number of grains (37.133 spike^{-1}) was recorded in weedy check both at 60 days after herbicides application. The maximum number of grains spike^{-1} in hand weeding as well as herbicide treatments might be due to eradication of weeds and provision of greater amount of nutrients which produced larger spikes. Shahid et al. (2005) also reported greater number of grains per spike by adopting manual and chemical weed control practices.

1000-grain weight (g)

The data given in (Table 8) showed that the time of application of herbicides, herbicidal affect and their interaction had no significant effect on grain weight of wheat. However, among treatments, heavier grains (52.400 g) were recorded in hand weeded plots whereas weedy check produced lighter (46.793 g) grain weight. As far as the time of herbicides application is concerned, maximum grain weight of 50.154 g was noted at 30 days after herbicides application. Similarly, the interaction of treatments showed that hand weeded plots produced 52.840 g grain weight whereas weedy check produced 46.477 g grain weight both at 30 days after herbicides application. The heavier grains in hand weeded and herbicides treated plots might be due to availability of more resources in terms of nutrients and favorable soil environment. Ahmad et al. (2001) also found maximum grains of wheat under manual and chemical weed control practices.

Table 7 - Number of grains (spike^{-1}) as affected by time of different herbicides application in wheat

Herbicide name	Application time		Mean
	30 DAS	60 DAS	
H_1 = Plate Form (Clodinafop)	43.600 ^{NS}	40.633	42.117 ^{NS}
H_2 = Killfop (Clodinafop)	43.267	41.533	42.400
H_3 = Wheat Star (Tribenuron + Fluraxypyr + Clorophyralid)	40.500	44.067	42.283
H_4 = Clincher (Bromoxinal + MCPA)	40.967	37.133	39.050
H_5 = Bromax (Bromoxinal + MCPA)	40.600	40.233	40.416
H_6 = Pujjing (Fenoxaprop-p-ethyl)	40.067	39.867	39.967
H_7 = Selector (Bromoxinal + MCPA)	41.833	39.967	40.900
H_8 = Staraine M (Fluraxypyr)	39.167	42.400	40.783
H_9 = Axial (Propinocarb)	40.367	38.400	39.383
H_{10} = Buctril Super (Bromoxinal + MCPA)	41.200	38.167	39.683
H_{11} = Puma Super (Fenoxaprop-p-ethyl)	41.033	42.267	41.650
H_{12} = Atlantis (Tribenuron + Metsulfuron)	43.367	36.233	39.800
H_{13} = Alymax (Mesosulfuron + Iodosulfuran)	39.467	41.400	40.433
H_{14} = Hand Weeding	43.967	43.900	43.933
H_{15} = Control (no weeding)	38.800	37.133	37.966
Mean	41.213 ^{NS}	40.249	

^{NS} Non-significant.

Table 8 - 1000 grain weight (g) as affected by time of different herbicides application in wheat

Herbicide name	Application time		Mean
	30 DAS	60 DAS	
H_1 = Plate Form (Clodinafop)	50.290 ^{NS}	47.903	49.097 ^{NS}
H_2 = Killfop (Clodinafop)	49.763	51.197	50.480
H_3 = Wheat Star (Tribenuron + Fluraxypyr + Clorophyralid)	46.893	48.030	47.462
H_4 = Clincher (Bromoxinal + MCPA)	51.310	50.040	50.675
H_5 = Bromax (Bromoxinal + MCPA)	51.479	46.479	48.979
H_6 = Pujjing (Fenoxaprop-p-ethyl)	50.393	51.500	50.947
H_7 = Selector (Bromoxinal + MCPA)	51.223	50.433	50.828
H_8 = Staraine M (Fluraxypyr)	50.200	48.580	49.390
H_9 = Axial (Propinocarb)	49.763	47.597	48.680
H_{10} = Buctril Super (Bromoxinal + MCPA)	51.453	51.610	51.532
H_{11} = Puma Super (Fenoxaprop-p-ethyl)	51.257	48.173	49.715
H_{12} = Atlantis (Tribenuron + Metsulfuron)	51.340	50.721	51.030
H_{13} = Alymax (Mesosulfuron + Iodosulfuran)	50.917	48.983	49.950
H_{14} = Hand Weeding	52.840	51.960	52.400
H_{15} = Control (no weeding)	46.477	47.340	46.793
Mean	50.154 ^{NS}	49.126	

^{NS} Non-significant.

Grain yield (ton ha^{-1})

The data given in (Table 9) indicated that the time of herbicides application significantly affected grain yield of wheat. The maximum grain yield of 4.3438 ton ha^{-1} was obtained at 30 days after herbicides application. Similarly, among various herbicides, maximum grain yield (5.1216 ton ha^{-1}) was recorded in hand weeded plots than all other treatments including weedy check which produced grain yield of 3.5783 ton ha^{-1}. The interaction of time of herbicides application and herbicidal effects revealed that Wheat star produced maximum grain yield (5.2200 ton ha^{-1}) at 60 days after herbicides application. It was, however, statistically at par with

Table 9 - Grain yield (ton ha^{-1}) as affected by time of different herbicides application in wheat

Herbicide name	Application time		Mean
	30 DAS	60 DAS	
H_1 = Plate Form (Clodinafop)	4.0800 ab	4.4433 ab	4.2617 ^{NS}
H_2 = Killfop (Clodinafop)	4.3833 ab	4.2733 ab	4.3283
H_3 = Wheat Star (Tribenuron + Fluraxypyr + Clorophyralid)	4.2467 ab	5.2200 a	4.7333
H_4 = Clincher (Bromoxinal + MCPA)	4.4133 ab	4.3333 ab	4.3733
H_5 = Bromax (Bromoxinal + MCPA)	4.7100 ab	3.4967 ab	4.1033
H_6 = Pujjing (Fenoxaprop-p-ethyl)	3.6100 ab	4.3867 ab	3.9983
H_7 = Selector (Bromoxinal + MCPA)	4.5500 ab	4.4700 ab	4.5100
H_8 = Staraine M (Fluraxypyr)	4.4100 ab	4.4133 ab	4.4117
H_9 = Axial (Propinocarb)	3.6100 ab	4.2866 ab	3.9483
H_{10} = Buctril Super (Bromoxinal + MCPA)	4.5533 ab	3.5400 ab	4.0467
H_{11} = Puma Super (Fenoxaprop-p-ethyl)	4.1367 ab	4.2200 ab	4.1783
H_{12} = Atlantis (Tribenuron + Metsulfuron)	4.9933 ab	3.9933 ab	4.4933
H_{13} = Alymax (Mesosulfuron + Iodosulfuran)	4.6633 ab	4.1333 ab	4.3983
H_{14} = Hand Weeding	5.1633 a	5.0800 a	5.1216
H_{15} = Control (no weeding)	3.6333 ab	3.5233 ab	3.5783
Mean	4.3438 a	4.1147 b	

$LSD_{0.05}$ (Application time) = 0.145, $LSD_{0.05}$ (Interaction) = 2.541, Different letters are shown statistically significant at 5% probability. ^{NS} Non-significant.

hand weeding which produced 5.1633 and 5.0800 ton ha^{-1} at 30 and 60 days after herbicides application respectively. Ali et al. (2004) evaluated different herbicides and reported that all the herbicides significantly increased plant height, fertile tillers m^{-2}, grains spike^{-1} and 1000-grain weight which ultimately enhanced grain yield. Similarly, Abbas et al. (2009) reported that herbicidal applications out yielded the control. Mahmood et al. (2013) evaluated the efficacy of various herbicides and noted that herbicide increased grain yield of wheat by 42% and also increased tillers per unit area, spike length, number of grains per spike, 1000-grain weight over weedy check.

This study concludes that wheat variety Gomal-8 produced the highest grain yield in plots where manual weeding was done. Hand weeded plots produced lower weed population and higher chlorophyll content, leaf area index, plant height, number of tillers, spike length, number of grains per spike, 1000-grain weight, biological yield and harvest index. Therefore, it is highly recommended for the farmers to cultivate wheat variety Gomal-8 along with all other recommended cultural and agronomic practices for getting maximum grain yield under the agro-ecological condition of Dera Ismail Khan.

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