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Response of Poaceous Weeds in Wheat to Post-Emergence Herbicides

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Abstract
Poaceous weeds are prolific and competitive in winter crops, but they are more insidious in wheat due to their similar morphology and growing requirements. Herbicides are effective and efficient tools of weed management, however, they are vulnerable to resistance, and herbicides with different modes of action might check the dominance of a particular weed flora. The current study was undertaken to see the response of three poaceous weeds *viz*., *Phalaris minor, Avena fatua* and *Lolium temulentum*, to herbicides Isoproturon, Topik (Clodinafop-p) and Puma Super (Fenoxaprop-p). Completely randomized design with two factor treatments (weeds, herbicides) and eight replications was employed. Data were recorded on chlorotic and necrotic effects of herbicides on weeds, and percent mortality at the time interval of 14, 21 and 28 days after the application of herbicides. Dry biomass weight of weeds was recorded at 30 days after the treatments. Results indicated that all the parameters were affected significantly over the period of time. Maximum counts of chlorotic (2.16) and necrotic (2.97) weeds were observed at the 21st day of treatment. The highest mortality (31.1 %) was recorded at 21st day after the application of herbicides. *Phalaris minor* was the most resistant weed to herbicides showing the lowest mortality (only 17.7 %) compared to other two weeds. Maximum dry weight of weeds was recorded in control while a minimum of 0.456 g dry weight was observed where Topik (Clodinafop-p) was applied. For the effective control of *P. minor, A. fatua* and *L. temulentum* weeds in wheat crop, Topik (15 WP) @ 0.37 kg a.i. ha^{-1} was proved to be the most suitable herbicide applied at 3-4 foliar stage.

Key words: *Avena fatua*, Clodinafop-p, Fenoxaprop-p, Herbicides; Isoproturon, *Lolium temulentum, Phalaris minor*, Weeds

Introduction

Wheat (*Triticum aestivum* L.) occupies about 17 % of the world's cropped land and contributes 35 % of the staple food (Pingali, 1999). It is a staple food for a large population, and its increased production is essential for food security (Chhokar *et al.*, 2006).

Weeds constitute one of the biggest problems in agriculture, causing big losses ranging from 17.3 % (Pervaiz & Quazi, 1992) to 30 % (Khan & Noor, 1995) to the wheat crop. They reduce water flow in irrigation and drainage channels, increase harvesting costs, require costly cleaning of seeds, and increase fire hazards. Weeds not only reduce the yield and quality of crops but also utilize scarce and essential nutrients and moisture (Singh *et al.*, 1999). On average, weeds utilize 40, 7 and 35 kg ha^{-1} of N, P, and K, respectively, in wheat (Singh & Malik, 1992). The deteriorated quality of farm produce results in decreased market value. The economic losses on annual basis due to weeds in wheat amount to more than Rs. 28 billion at national level in Pakistan and Rs. 2 billion in its NWFP province (Hassan & Marwat, 2001).

The common annual grass (Poideae) weeds particularly *P. minor* Retz, *A. fatua* L. and *L. temulentum* L. infest winter season crops including wheat and may seriously affect their yield and quality. These weeds occur in several winter crops, but they have become more pernicious in wheat due to their morphology and growing requirements similar to wheat during the early stages of development (Singh *et al.*, 1999).

Phalaris minor (common name littleseed canary grass; local name dumbi siti) is one of the most dominant and troublesome weed of wheat fields. Its origin is Mediterranean.

Among the ten important weeds in Pakistan, *P. minor* was reported to be the most dominant (Ghafoor *et al.*, 1987). It also causes severe wheat lodging and makes harvesting operations difficult, and has become a real threat to the sustainability of wheat production (Chhokar *et al.*, 2006). Recently, *P. minor* has become resistant to the phenyl urea herbicide isoproturon applied to wheat crop, and therefore, problematic in the successful cultivation of winter season crops (Singh e*t al.*, 1999; *Chhokar et al.*, 2006).

Avena fatua (common name wild oats; local name jungli jai), its origin and history probably began in the Mediterranean and some believe the species originated in Central Asia. It is widely spread through out the world, a weed of over 20 crops in 55 countries. As a consequence of its persistence and its impact upon yields, *A. fatua* leads to significant economic losses in the grain growing regions (Jones & Medd, 1997). Worldwide *A. fatua* is highly resistant to a number of herbicides (Stokosa *et al.*, 2006).

Lolium temulentum (common name Italian grass; local name khiwi) is another important grassy weed which is on the increase as it is spreading with the crop seed. Its origin is Mediterranean region and South West Asia, and is found throughout its range as a weed of grain crops. It is annual grass with erect or geniculate at the base and slender to moderately stout.

The dependence on herbicides has increased with the development of high yielding, but less competitive cultivars (Chhokar *et al.*, 2006). Chemical weed control outperforms mechanical and manual methods, except with resistant weed biotypes. Investing 1$ on herbicides generated an additional 9$ by increased wheat yields in India (Singh *et al.*, 1999). The significant reduction in weed biomass is observed in wheat crop by using herbicides. Shamsi *et al.* (2001) indicated that herbicides are the most effective formulation, reducing weed density and dry matter accumulation, giving highest grain yield of wheat. The increased yield obtained under herbicide treated fields was a function of 59, 50 and 46 % higher uptake of N, P, and K ha-1 by wheat compared with unweeded conditions; application of herbicides increased N efficiency of wheat from 50 to 90 % (Singh & Malik, 1992). The herbicide performance depends upon plant response, selectivity and translocation pattern. Thus, the application of recommended rates of fertilizer and herbicide provided an 85 % higher gross margin compared to unweeded conditions (Walia & Gill, 1985).

Among herbicides, isoproturon was extensively used by farmers due to its broad-spectrum weed control and flexibility in application timing and method. The dependence on isoproturon led to development of resistance in P. minor against this herbicide (Malik & Singh, 1995; Chhokar *et al.*, 2002). The continuous dependence on a single herbicide for a long time, besides resistance development, also leads to a shift in the weed flora (Chancellor, 1979). For decreasing selection pressure in favour of resistant biotypes / tolerant weed species and to sustain wheat production, the use of new herbicides and mixtures having different modes of action is necessary (Chhokar *et al.*, 2006). Alternative herbicides (clodinafop, fenoxaprop, tralkoxydim and sulfosulfuron) for the control of isoproturon-resistant weeds could be examined; as sulfosulfuron has been found effective for control of P. minor and many broad-leaved weeds in wheat (Chhokar *et al.*, 2002).

Significant differences were recorded by Khan *et al.* (2003) for various herbicides in the traits like weed density and wheat tillers count. Weeds were most effectively controlled by Buctril-M + Topik, Isoproturon alone and Logran + Topik. Inhibition of the enzyme Acetyl CoA carboxylase takes place by clodinafop-p (Topik) and fenoxaprop-p (Puma Super) application finally inhibiting the biosynthesis of fatty acids resulting in the failure of membrane formation and ultimate senescence of susceptible plants.

In view of the resistance development in poaceous weeds to some herbicides, this study was undertaken to see the impact of different herbicides for the control of these noxious weeds.

Materials and Methods

The experiment was conducted in a greenhouse according to two factors factorial completely randomized design (CRD) with combination of three weed species and three herbicides having eight replications. Before starting the experiment, germination test of three weed species seeds was conducted in the laboratory. For experiment, sixteen (16) seeds of

Table 1. Description of herbicides used in the experiment

Trade name	Common name	Chemical name	Rate (kg a.i*/ha)
Isoproturon (75WP)	Isoproturon	N-(4-Isopropyl phenyl)-N, N-dimethyl urea	1.12
Topik (15WP)	Clodinafop-p	2-Propynl-(R)-2-(4-5-Chloro-3-fluoro-2-Pyridyloxy-Phenoxy) propionate	0.37
Puma Super (75EW)	Fenoxaprop-p	Ethyl,(D+)-ethyl-2-(4-(6chloro-2-benzoxazolyloxy)-phenoxy)-propionate	0.75

each weed were sown in respective treatment pots. After germination, twelve (12) healthy seedlings were maintained in each pot to apply pesticide treatments. Weed plants were treated with three herbicides at 3-4 leaf stage when the weeds were actively growing. Table 1 presents the chemical and brand names, and relative concentrations of herbicides applied during the experiment. The two factors treatments compared in the experiment were as under:

Factor 1 (weed species)

1-*Phalaris minor* (common name Canary grass and local name dumbi siti)

2-*Avena fatua* (common name wild oats and local name jungli jai)

3-*Lolium temulentum* (common name Italian grass and local name khiwi)

Factor 2 (herbicides)

1-Isoproturon 75WP (common name Isoproturon) @ 1.12 kg a.i*/ha

2-Topik 15 WP (common name Clodinafop-p) @ 0.37 kg a.i*/ha

3-Puma Super 75 EW (common name Fenoxaprop-p) @ 0.75 kg a.i*/ha

4-Control (no herbicide applied)

These two factors treatments were tested in combination making a total of nine treatments. Data were collected at the time intervals of 14, 21 and 28 days after the application of herbicides treatments. Therefore, time interval was considered as Factor 3 while statistical analysis of the data recorded at these stages. Irrigation and all other agronomic practices were employed equally to all the treatments. Observations on chlorotic / necrotic weeds count and mortality rate were recorded at 14, 21 and 28 days after herbicides application, while dry biomass weight was recorded only once at 30th day.

Mortality rate was calculated by employing the following equation: Mortality rate (%) = No. of weeds died after treatment × 100 / No. of weeds before treatment

Harvested weeds were initially sun dried and then kept in the oven at 105 °C overnight for obtaining constant dry weight. Data collected on different weed characteristics as affected by time interval, weed species and herbicides were subjected to statistical analysis by using ANOVA technique under CRD three factors factorial design (Steel & Torrie, 1980). Least significant difference (LSD) test at $p<0.05$ was applied to decide the best herbicide for the control of subject weeds.

Results and Discussions

Resistance of weeds to traditional herbicides was measured through observations on the number of weeds affected by chlorosis, necrosis and mortality compared with the total original population of weeds as 16 plants in each treatment pot. Further, the reduced biomass weight was taken as an indicator for the effectiveness of herbicides. In the following paragraphs, the results of all the parameters are discussed separately.

Chlorotic Weeds

All the three factors and their interactions affected the number of chlorotic weeds significantly. Amongst time intervals, significantly higher chlorotic weeds (only 2.16) were observed after 21 days of treatment compared to even lower count at 14th and 28 th day; which were found statistically at par (Table 2). Results indicated that the herbicides were effective only a little even at the 21st day to cause chlorotic effect on few weeds against a total original number of 16 weeds per pot. As far as weed species are concerned maximum number of chlorotic plants (1.68) was observed for *P. minor* followed by *A. fatua* and *L. temulentum* with 1.01 and 0.760 chlorotic plants, respectively, which proved to be much resistant to herbicides. All the three herbicides were found to be at par while no chlorotic

Table 2. Chlorotic effect of herbicides on weeds (# of chlorotic weeds pot^{-1}) w.r.t. time

Treatments	Factor C (Herbicides = H)				Average
	Isoproturon	Topik	Puma Super	Control	
Factor A (Days = D)		**Interaction A × C**			**A**
D14	0.67 de*	1.17 c	1.04 c	0.00 f	0.70 B*
D21	2.75 ab	3.17 a	2.58 b	0.00 f	2.16 A
D28	1.00 c	0.38 e	0.96 cd	0.00 f	0.58 B
Factor B (Weeds = W)		**Interaction B × C**			**B**
W1 *Phalaris minor*	2.17 b	2.08 b	2.50 a	0.00 e	1.69 A
W2 *Avena fatua*	1.42 c	1.33 c	1.29 c	0.00 e	1.01 B
W3 *Lolium temulentum*	0.96 d	1.33 c	0.75 d	0.00 e	0.76 C
Factor A × Factor B		**Interaction A × B × C**			**A × B**
D14 × W1	0.88 defg	2.00 c	2.00 c	0.00 i	1.22 C
D14 × W2	0.88 defg	0.50 fghi	0.75 efgh	0.00 i	0.53 E
D14 × W3	0.25 gi	1.00 def	0.38 ghi	0.00 i	0.41 EF
D21 × W1	4.25 a	3.25 b	4.13 a	0.00 i	2.91 A
D21 × W2	3.13 b	3.25 b	3.13 b	0.00 i	2.38 B
D21 × W3	1.25 de	3.00 b	0.50 fghi	0.00 i	1.19 C
D28 × W1	1.38 d	1.00 def	1.38 d	0.00 i	0.94 CD
D28 × W2	0.25 hi	0.13 i	0.13 i	0.00 i	0.13 F
D28 × W3	1.38 d	0.00 i	1.38 d	0.00 i	0.69 DE
Average C	1.51 A*	1.57 A	1.53 A	0.000 B	

* Average values in a column or row, and interactions bearing dissimilar letters have a statistically significant difference at $p<0.05$.

weed was recorded in control.

The interaction between time interval and weed species (A × B) shows that maximum chlorotic plants 2.906 were of *P. minor* followed by *A. fatua* (2.375) and *L. temulentum* (1.19) at 21 days after the application of herbicides. The interaction between time interval and herbicides (A × C) showed that maximum of 3.17 chlorotic plants were after 21 days of treatment in Topik treated pots, followed by Isoproturon (2.75 plants) and Puma Super (2.58 plants) while no chlorotic weed was recorded in control. Interaction of weed species with herbicides (B × C) showed maximum chlorotic plants of *P. minor* (2.50) in Puma Super treated pots followed by Topik and Isoproturon treated pots. Singh *et al.* (1999) and Chhokar *et al.* (2006) also advocated that *P. minor* has become resistant to the phenyl urea herbicide isoproturon applied to wheat crop, and therefore, problematic in the successful cultivation of winter season crops. For *A. fatua* maximum of 1.42 chlorotic plants were seen in Isoproturon treated pots while maximum of 1.333 chlorotic plants of *L. temulentum* were recorded in Topik treated pots. Stokosa *et al.* (2006) also reported that *A. fatua* is highly resistant to a number of herbicides.

The interaction among three factors (A × B × C) showed that maximum chlorotic plants of 4.13 *P. minor* were in Puma Super treated pots at 21 days after the application of herbicides. No chlorotic weed was seen in control across all time intervals and weed species. These results are in line with those of Welch and Ross (1997) who found that chlorotic and necrotic effects appeared within 2-3 weeks after treatment with herbicides and gradually increased to the death of plants.

Necrotic Weeds

All the factors and their interactions affected the number of necrotic weeds significantly ($p<0.05$). The highest number of necrotic weeds (2.96) was recorded at 21 days after the treatment, followed by 28 days (2.15 plants) and 14 days (0.51 plants), respectively (Table 3). As far as weed species are concerned, maximum numbers of necrotic plants (2.20) were observed for *A. fatua*, followed by *L. temulentum* having 1.81 and *P. minor* having 1.63 necrotic plants. Amongst the herbicides, Topik treated weeds had significantly higher number of 2.76 necrotic plants while Puma Super and Isoproturon were non significantly

Table 3. Necrotic effect of herbicides on weeds (# of necrotic weeds pot^{-1}) w.r.t. time

Treatments	Factor C (Herbicides = H)				Average
	Isoproturon	Topik	Puma Super	Control	
Factor A (Days = D)		**Interaction A × C**			**A**
D14	0.58 f*	1.00 e	0.46 f	0.00 g	0.51 C*
D21	3.63 b	4.13 a	4.13a	0.00 g	2.97 A
D28	2.88 cd	3.17 c	2.58 d	0.00 g	2.16 B
Factor B (Weeds = W)		**Interaction B × C**			**B**
W1 *Phalaris minor*	1.88 c	2.33 b	2.29 b	0.00 d	1.63 C
W2 *Avena fatua*	2.98 a	2.88 a	3.00 a	0.00 d	2.20 A
W3 *Lolium temulentum*	2.29 b	3.08 a	1.88 c	0.00 d	1.81 B
Factor A × Factor B		**Interaction A × B × C**			**A × B**
D14 × W1	0.63 g	1.88 e	0.75 fg	0.00 h	0.81 E
D14 × W2	0.63 g	0.50 gh	0.63 g	0.00 h	0.44 F
D14 × W3	0.50 gh	0.63 g	0.00 h	0.00 h	0.28 F
D21 × W1	0.75 fg	1.88 e	2.00 e	0.00 h	1.16 D
D21 × W2	5.00 b	4.88 b	5.25 ab	0.00 h	3.78 A
D21 × W3	5.13 ab	6.53 a	5.13 ab	0.00 h	3.97 A
D28 × W1	4.25 c	3.250 d	4.13 c	0.00 h	2.91 B
D28 × W2	3.13 d	3.250 d	3.13 d	0.00 h	2.38 C
D28 × W3	1.25 f	3.000 d	0.50 gh	0.00 h	1.88 D
Average C	2.36 B*	2.764 A	2.39 B	0.00 C	

* Average values in a column or row, and interactions bearing dissimilar letters have a statistically significant difference at $p<0.05$.

different from each other. The results are in agreement with Masood *et al* (2002), who also observed effectiveness of Isoproturon. The interaction of time interval and weed species shows that the highest necrotic plants (3.97) were of *L. temulentum* which were statistically at par with *A. fatua* (3.78) at 21 days after the application of herbicides. Maximum of 4.13 necrotic plants were recorded after 21 days of treatment in Topik and Puma Super treated pots respectively followed by Isoproturon 3.63 plants while no necrotic weed was seen in control. Khan *et al.* (2001) also found that Puma Super controlled *P. minor* and *A. fatua* successfully by reducing their density in wheat to a maximum.

Mortality Rate

The effects of time interval, weed species, herbicides and all interactions of these factors were significant on the mortality rate of weeds (Table 4). Within time interval, highest mortality of 31.1 % was recorded after 21 days of treatment, followed by 22.9 and 5.4 % mortality at 28 and 14 days, respectively. As far as weed species are concerned, *A. fatua* showed maximum of 22.3 percent mortality followed by *L. temulentum* and *P. minor*. However, the later two were not significantly different from each other. Amongst herbicides, the highest mortality rate (29.6 %) was recorded with Topik, while no mortality was seen in control. However, a small number of plants in any weed population are likely to be naturally resistant to a given herbicide.

The interaction of time interval and weed species showed the maximum mortality (41.6 %) of *L. temulentum* at 21 days after the treatment; while minimum of 2.8 % was recorded 14 days after the treatment in *L. temulentum* pots. After 21 days of treatment maximum of 43.2 % mortality was recorded in Puma Super treatment as compared to no mortality in control. The effect of Puma Super was at par with Topik at 21 days after

Table 4. Mortality rate of weeds (%) caused by traditional herbicides w.r.t. time

Treatments	Factor C (Herbicides = H)				Average
	Isoproturon	Topik	Puma Super	Control	
Factor A (Days = D)		**Interaction A × C**			**A**
D14	5.9 f*	10.8 e	5.0 f	0.0 g	5.4 C*
D21	37.4 b	43.9 a	43.2 a	0.0 g	31.1 A
D28	30.2 d	34.2 c	27.4 d	0.0 g	22.9 B
Factor B (Weeds = W)		**Interaction B × C**			**B**
W1 Phalaris minor	20.3 d	26. 1 c	24.3 c	0.0 e	17.7 B
W2 Avena fatua	29.5 b	29.9 b	31.8 ab	0.0 e	22.3 A
W3 Lolium temulentum	23.6 c	32.9 a	19.5 d	0.0 e	19.0 B
Factor A × Factor B		**Interaction A × B × C**			**A × B**
D14 × W1	6.7 h	21.5 f	8.8 gh	0.0 i	9.2 E
D14 × W2	5.96 h	4.8 hi	6.2 h	0.0 i	4.2 F
D14 × W3	5.1 hi	6.3 h	0.0 i	0.0 i	2.8 F
D21 × W1	8.5 gh	20.7 f	20.3 f	0.0 i	12.4 D
D21 × W2	50.8 bc	51.0 b	55.8 ab	0.0 i	39.4 A
D21 × W3	52.8 b	60.0 a	53.5 b	0.0 i	41.6 A
D28 × W1	45.8 cd	36.2 e	43.6 d	0.0 i	31.4 B
D28 × W2	31.7 e	33.9 e	33.3 e	0.0 i	24.7 C
D28 × W3	13.0 g	32.4 e	5.2 h	0.0 i	12.6 D
Average C	24.5 B*	29.615 A	25.2 B	0.0 C	

* Average values in a column or row, and interactions bearing dissimilar letters have a statistically significant difference at $p<0.05$.

the treatment. Maximum of 32.9 % mortality was recorded in *L. temulentum* pots where Topik was applied followed by 31.758 % mortality in *A. fatua* pots where Puma Super was applied as compared to no mortality in control. Chhokar *et al.* (2006) also found that Isoproturon at 1 and 2 kg a.i. ha^{-1}) provided only 10.5 % and 51.8 % *P. minor* control, respectively. Maximum of 60.0 % mortality was observed in *L. temulentum* pots where Topik was applied 21 days after the treatment followed by 53.5 % mortality in *A. fatua* where Puma Super was applied as compared to no mortality in control. The results coincide with those of Tysoe (1975) and Manning *et al.* (1993).

Dry Biomass Weight

Dry weight of different weed species was found non significantly different from each other; while herbicides, and weed × herbicide interaction were affected significantly (Table 5). Amongst the herbicides minimum weeds dry weight (0.46 g) was recorded in Topik treated pots as compared to maximum, of 5.98 (g) in control. As far as the interaction is concerned, minimum weight (0.41 g) of *A. fatua* was recorded when treated with Puma Super. All the plants of *L. temulentum* died, when treated with Topik while maximum weight of 6.57 (g) was recorded in control pots of *A. fatua* which was at par with the weight of *P. minor* in control pots. The results are in line with the findings of Balyan *et al.* (1994), Dhawan (1995) and Angiras *et al.* (1996) who also stated that herbicidal applications decreased the weed dry matter.

Conclusion

For the control of poaceous weeds in wheat crop, the herbicide Topik (15 WP) @ 0.37 kg a.i. ha^{-1} was proved to be the most suitable herbicide applied at 3-4 foliar stage. However, all the three tested herbicides were having their best effect at 21 days after their application. Among three weed species, *P. minor* was found to be most resistant to the tested herbicides in terms of mortality rate and biomass weight.

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Table 5. Dry biomass of weeds (g pot^{-1}) under herbicides application at 30 days after treatment

Herbicides	Weed species			Mean
	P. minor	*A. fatua*	*L. temulentum*	
Isoproturon	1.00 cde	0.75 efg	1.25 cd	**1.00 B**
Topik	0.48 fg	0.89 def	0.00 h	**0.46 C**
Puma Super	0.64 efg	0.41 gh	1.42 c	**0.82 B**
Control	6.52 a	6.57 a	4.84 b	**5.98 A**
Mean	**2.16 A**	**2.15 A**	**1.88 B**	

* Average values in a column or row, and interactions bearing dissimilar letters have a statistically significant difference at $p<0.05$.

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