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Ready mix of pinoxaden and clodinafop-propargyl for control of *Phalaris minor* in wheat and its residual effects on succeeding rice crop

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ABSTRACT

A field experiment to evaluate the efficacy of a pre-mix herbicide pinoxaden 2.53% + clodinafop 2.53% w/w (Traxos 5% EC) against grassy weed *Phalaris minor* in wheat was conducted during winter season 2011-12 and 2012-13 at CCS Haryana Agricultural University, Regional Research Station, Karnal. Density and dry weight of *P. minor* under pinoxaden + clodinafop 60 g/ha was at par to pinoxaden 50 g/ha but lower than clodinafop 60 g/ha and fenoxaprop 120 g/ha. However, the differences with clodinafop in respect of dry weight of *P. minor* were not significant. Pinoxaden + clodinafop 60 g/ha provided control of *P. minor* as good as weed free check, and resulted in higher number of effective tillers than its lower dose (40 g/ha), fenoxaprop 120 g/ha and weedy check. This ready mix provided grain yield of wheat similar to pinoxaden 50 g/ha, clodinafop 60 g/ha and weed free check but higher than fenoxaprop 120 g/ha during both the years, and there was no phyto-toxicity on wheat. There was also no phyto-toxicity of pinoxaden + clodinafop up to 120 g/ha on succeeding rice crop.

INTRODUCTION

Wheat (*Triticum aestivum*) the most staple food crop in North-Western India is often infested with weeds particularly *Phalaris minor* causing large scale yield reductions (Chhokar *et al*. 2012). *Phalaris minor* evolved resistance first against isoproturon during 1992-93 due to its continuous use for more than 10-15 years coupled with rice-wheat mono-cropping resulting into total crop failure/immature crop harvest as fodder (Malik and Singh 1995). Consequently, the recommendation of isoproturon was displaced with alternate herbicides during 1997-98 and thereafter. But many alternate herbicides including clodinafop-propargyl, fenoxaprop-ethyl, sulfosulfuron and pinoxaden recommended to control this problematic grass weed have also been rendered ineffective due to the evolution of resistance (Brar *et al*. 2002, Dhawan *et al*. 2012, Kaur *et al*. 2016). This further warrants for screening of alternate herbicides alone or in combination as herbicides would stay as the most important tool against resistant *P. minor*.

The availability of new molecules with different mode of action but same level of activity against *P. minor* is limited. Suitable herbicide combinations should reduce selection pressure for resistance development and manage the weeds effectively. Herbicide combinations (ready/pre- mix or tank-mix) have been reported to provide better control of weeds compared to single herbicide (Singh 2015, Singh *et al.* 2015, Yadav *et al.* 2016, Kaur *et al.* 2017, Punia *et al*. 2017) besides delaying herbicide resistance. Similarly, it was hypothesized that pre-mix combination of pinoxaden + clodinafop would provide amicable solution against herbicide resistant *P. minor*. Therefore, to manage resistant *Phalaris minor*, bio-efficacy of a new pre-mix herbicide (pinoxaden 2.53% + clodinafop-propargyl 2.53% w/w) (Traxos 5% EC) was evaluated to optimize its use rate against *P. minor* in wheat. To further make it sure that it is safe to succeeding rice crop, its residual effects were also investigated at 60 and 120 g/ha.

MATERIALS AND METHODS

A field experiment to evaluate the efficacy of a new pre-mix herbicide pinoxaden 2.53% + clodinafop 2.53% w/w (Traxos 5% EC) for *Phalaris minor* control in wheat was conducted during *Rabi* 2011-12 and 2012-13 at CCS Haryana Agricultural University, Regional Research Station, Karnal. The soil of the experimental field was low in organic carbon (0.35 %), medium in available phosphorous (11 kg/ha) and potassium (280 kg/ha) with slightly alkaline in reaction (pH 8.2) The treatments included pinoxaden

+ clodinafop 5% EC 40, 50, 60 and 120 g/ha, in comparison to pinoxaden 5% EC 50 g/ha, clodinafop 15% WP 60 g/ha, fenoxaprop 10% EC 120 g/ha along with weed free and weedy checks. The treatments were laid out in randomized block design (RBD) with three replications. Wheat cultivar '*DPW 621-50*' was sown on 19 November 2011 during 2011-12 and 20 November 2012 during 2012-13 at a row spacing of 20 cm using seed rate of 100 kg/ha. Plot size was 5.4 x 2.2 m. The herbicides were sprayed at 35 days after sowing (DAS) with knapsack sprayer fitted with flat fan nozzle using water volume of 500 l/ha on 24 December 2011 and 25 December 2012. Density and dry weight of weeds was recorded at 75 DAS. Phyto-toxicity of pinoxaden + clodinafop at 60 and 120 g/ha in terms of chlorosis, necrosis and yellowing was recorded at 1, 2, 3, 4, 5 weeks after treatment (WAT). Crop was raised according to package of practices of the state University and harvested on 26 April 2012 and 23 April 2013.

To study the residual effects of pinoxaden + clodinafop at 60 and 120 g/ha compared to untreated check, three additional plots of 5.4 x 4.4 m size replicated thrice were maintained separately in the same experimental field during 2011-12 and 2012-13. Wheat cultivar, sowing time, seed rate, herbicide spraying schedule were similar to the main experiment on bio-efficacy evaluation, as already explained. Similarly, these plots were harvested along with the main experiment. Then the plots were ploughed once in dry field condition (one week before rice transplanting) *fb* irrigation and puddling (1-2 days before transplanting). Transplanting of rice cultivar '*HKR47*' in these plots was done on 11 July 2012 and 7 July 2013 at 20 cm x 15 cm spacing. Rice crop was raised according to package of practices of the state University and harvested on 23 October 2012 and 21 October 2013. Phyto-toxicity in terms of chlorosis, necrosis and yellowing was recorded at 10, 20 and 30 days after transplanting (DAT). Grain yield of rice was also recorded at harvest.

Before statistical analysis, the data on density of weeds were subjected to square root $(\sqrt{x+1})$ to improve the homogeneity of the variance. All the data were subjected to the analysis of variance (ANOVA) separately for each year for better understanding of the results. The significant treatment effect was judged with the help of 'F' test at the 5% level of significance. The 'OPSTAT' software of CCS Haryana Agricultural University, Hisar was used for statistical analysis (Sheoran *et al.* 1998). This software uses type 1 sum of squares in ANOVA for simple RBD, with LSD (least significant difference) being used for multiple comparisons.

RESULTS AND DISCUSSION

Effect on weeds

Phalaris minor was the dominant grass weed in the research plots. Density and dry weight of *Phalaris minor* decreased with increase in dose of the pinoxaden + clodinafop from 40 to 50 and 60 g/ha during both the years (**Table 1**). Density and dry weight of *P. minor* in plots treated with pinoxaden + clodinafop 60 g/ha was similar to the check herbicide pinoxaden 50 g/ha, but lower than clodinafop 60 g/ha (except dry weight) and fenoxaprop 120 g/ha. Pinoxaden + clodinafop 60 g/ha provided control of *P. minor* comparable to weed free check, with weed control efficiency of 99.3 and 98.5% during 2011-12 and 2012-13, respectively. Singh *et al.* (2015) and Kaur *et al.* (2017) have also reported effective control of resistant *P. minor* with post-emergence application of pinoxaden + clodinafop 50-60 g/ha in wheat.

Table 1. Effect of pinoxaden 2.53% + clodinafop-propargyl 2.53% w/w (5% EC) and other herbicidal treatments on density and dry weight of grassy weeds in wheat (2011-12 and 2012-13)

Treatment	Density of *P. minor* (no./m^2)*		Dry weight of grassy weeds (g/m^2)		Weed control efficiency (%)	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Pinoxaden + clodinafop-propargyl (40 g/ha)	8.21 (66.7)	4.57 (20.0)	15.9	19.8	88.3	86.2
Pinoxaden + clodinafop-propargyl (50 g/ha)	5.19 (26.0)	4.03 (15.3)	7.4	9.9	94.5	93.1
Pinoxaden + clodinafop-propargyl (60 g/ha)	3.68 (12.7)	2.76 (6.7)	0.9	2.2	99.3	98.5
Pinoxaden + clodinafop-propargyl (120 g/ha)	3.26 (10.0)	1.82 (2.7)	0.9	1.9	99.3	98.7
Pinoxaden (50 g/ha)	3.77 (13.3)	2.99 (8.0)	1.7	2.1	98.7	98.5
Clodinafop (60 g/ha)	5.03 (24.7)	4.18 (16.7)	5.8	7.7	95.7	94.6
Fenoxaprop (120 g/ha)	7.16 (50.7)	5.36 (28.0)	14.8	21.3	89.1	85.2
Weed free	1.00 (0.0)	1.00 (0.0)	0.0	0.0	100.0	100.0
Weedy check	13.52 (182.7)	8.83 (77.3)	135.4	143.7	88.3	86.2
LSD (p=0.05)	1.21	1.01	5.0	5.7		

*The original figures in parentheses were subjected to square root transformation $(\sqrt{x+1})$ before statistical analysis

Table 2. Effect of pinoxaden 2.53% + clodinafop-propargyl 2.53% w/w (5% EC) and other herbicidal treatments on yield and yield attributes of wheat (2011-12 and 2012-13)

Treatment	Plant height (cm)		Effective tillers/ mrl		Earhead length (cm)		Grain yield (t/ha)	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Pinoxaden + clodinafop-propargyl (40 g/ha)	104.3	96.5	75.0	83.0	11.5	11.5	5.10	5.63
Pinoxaden + clodinafop-propargyl (50 g/ha)	104.9	95.9	79.5	85.2	11.6	11.5	5.31	5.82
Pinoxaden + clodinafop-propargyl (60 g/ha)	105.0	96.1	82.8	88.8	11.7	11.5	5.52	6.05
Pinoxaden + clodinafop-propargyl (120 g/ha)	103.1	95.1	76.3	83.5	11.5	11.4	5.16	5.79
Pinoxaden (50 g/ha)	104.7	96.3	81.5	86.5	11.7	11.6	5.43	5.91
Clodinafop (60 g/ha)	104.3	95.5	80.2	86.8	11.5	11.5	5.40	5.92
Fenoxaprop (120 g/ha)	103.7	95.9	74.0	82.3	11.5	11.5	5.05	5.61
Weed free	104.9	96.9	84.8	90.0	11.8	11.7	5.74	6.08
Weedy check	103.5	94.8	55.0	53.7	10.9	11.3	4.14	3.94
LSD (p=0.05)	NS	NS	5.0	4.1	0.4	NS	0.39	0.17

Abbreviations: mrl- Meter row length, NS- Non-significant

Table 3. Phyto-toxicity (0-10 scale) of pinoxaden 2.53% + clodinafop-propargyl 2.53% w/w (5% EC) on wheat (2011-12 and 2012-13)

Treatment	1 WAT		2 WAT		3 WAT		4 WAT		5 WAT	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Pinoxaden + clodinafop (60 g/ha)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinoxaden + clodinafop (120 g/ha)	0.0	0.0	1.0	0.7	2.0	1.3	1.7	1.3	1.3	1.0
Untreated check	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Abbreviations: WAT- Weeks after treatment

Table 4. Phyto-toxicity (0-10 scale) of pinoxaden 2.53% + clodinafop-propargyl 2.53% w/w (5% EC) on succeeding rice (2012 and 2013)

Treatment	Phytp-toxicity (0-10 scale)						Grain yield (t/ha)	
	2012			2013				
	10 DAT	20 DAT	30 DAT	10 DAT	20 DAT	30 DAT	2012	2013
Pinoxaden + clodinafop (60 g/ha)	0.0	0.0	0.0	0.0	0.0	0.0	6.94	6.52
Pinoxaden + clodinafop (120 g/ha)	0.0	0.0	0.0	0.0	0.0	0.0	6.88	6.65
Untreated check	0.0	0.0	0.0	0.0	0.0	0.0	6.90	6.58
LSD (p=0.05)							NS	NS

Abbreviations: DAT- Days after transplanting, NS- Non-significant

Effect on crop

Plant height of wheat was not affected by any of the treatments (**Table 2**). Pinoxaden + clodinafop 60 g/ha resulted in a greater number of effective tillers compared to its lower dose (40 g/ha), fenoxaprop 120 g/ha and weedy check; but similar to other check herbicides (pinoxaden 50 g/ha and clodinafop 60 g/ ha), and weed free check. The ear head length of wheat was similar under all the herbicide treatments though smeller ear heads were observed in weedy check plots during 2011-12 growing season.

Grain yield of wheat increased with successive increase in dose of pinoxaden + clodinafop 60 g/ha from 40 to 50 and 60 g/ha, however, the successive differences were significant during 2012-13 only (**Table 2**). During 2011-12, the grain yield under pinoxaden + clodinafop 60 g/ha was similar to 50 g/ha but significantly higher than 40 g/ha. Pinoxaden + clodinafop 60 g/ha resulted in grain yield similar to pinoxaden 50 g/ha, clodinafop 60 g/ha and weed free check but higher than fenoxaprop 120 g/ha during both the years. However, pinoxaden + clodinafop 40-50 g/ha resulted in lower wheat yield compared with the weed free check. Better weed management due to pinoxaden + clodinafop 60 g/ha resulted in to greater number of effective tillers and consequently higher yields. These results are in conformity with earlier findings elsewhere (Singh *et al.* 2015, Kaur *et al.* 2017).

Crop phyto-toxicity

There was no phyto-toxicity (in terms of chlorosis, necrosis and yellowing) of pinoxaden + clodinafop 60 g/ha in wheat. These results were in conformity with the findings of Kaur *et al.* (2017). However, there was phyto-toxicity of 1.3-2.0 (on 0-10 scale) at 120 g/ha on wheat crop at 3 WAT (**Table 3**); which recovered progressively with time.

Residual phyto-toxicity on succeeding rice crop

There was no phyto-toxicity (in terms of chlorosis, necrosis and yellowing) of pinoxaden + clodinafop 60 and 120 g/ha on succeeding rice crop during both the years (**Table 4**). The grain yield of rice in pinoxaden + clodinafop 60 and 120 g/ha treated plots in wheat and untreated check was similar. Kaur *et al*. (2017) also reported no residual phyto-toxicity pinoxaden + clodinafop 60 and 120 g/ha on succeeding crop of green gram.

Based on present investigation, it may be concluded that pinoxaden 2.53% + clodinafop-propargyl 2.53% w/w (5% EC w/v) 60 g/ha proved very effective against *Phalaris minor* resulting in improved grain yield of wheat, with no phyto-toxicity on the wheat crop. Also there was no phyto-toxicity up to 120 g/ha on succeeding rice crop. These results indicate it as a strong candidate as an alternative herbicide for management of herbicide resistant *Phalaris minor* in present situation.

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