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Article

Seed Pre-Treatment and Planting Geometry Positively Influence Herbicide Efficacy in Wheat (*Triticum aestivum*)

*Pré-Tratamento de Sementes e Geometria do Plantio Influenciam Positivamente a Aplicação de Herbicidas no Trigo (**Triticum aestivum**)*

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ABSTRACT - An experiment was conducted to evaluate the effect of priming, planting patterns and weed control treatments on weed spectrum, grain yield and profitability of wheat, during the growing season 2013-14. Two levels of seed priming (no priming, osmopriming) and planting patterns (broadcast, row plantation), and four levels of herbicide (pyroxulam at the rate of 14.08, 10.56, 7.04 and 7.521 g a.i. ha^{-1}) were employed in the experiment, laid out in a randomized complete block design with split-split plot arrangement. The data regarding weed density, stand establishment, growth, and yield associated traits of wheat were recorded and analyzed by analysis of variance technique using statistical software DSAASTAT. The results revealed that the final emergence count was improved significantly by line sowing. The seed priming treatments resulted in early crop emergence and canopy spread, and it also decreased weed density and dry weight by 13% and 18%, respectively at 60 DAS (days after sowing). Moreover, grain yield was improved by 8% in priming treatment plots. Whereas, line sowing of wheat treatment decreased the weed density and dry weight by 17% and 25% respectively, with improved grain yield by 14% over the broadcast method. Pyroxulam at the rate of 14.08 g a.i. ha^{-1} applied at 60 DAS reduced total weed density and dry weight by 88% and 96% respectively and grain yield was improved by 36% over weedy check plots. In conclusion, osmoprimed seeds (1% KCl) sown in lines 22.5 cm apart gave higher wheat yields where weeds were properly controlled through application of pyroxulam applied at its recommended dose (14.08 g a.i. ha^{-1}) and also 75% of recommended dose under Faisalabad conditions.

Keywords: seed priming, planting geometry, herbicides, weed spectrum.

RESUMO - Um experimento foi conduzido para avaliar os efeitos resultantes do sistema de pré-germinação, priming, padrões de plantio e tratamentos de controle de ervas daninhas sobre o espectro da erva daninha, rendimento de grãos e rentabilidade do trigo, durante o período de desenvolvimento da planta de 2013-14. As sementes foram preparadas de duas formas: sem a utilização do sistema de priming, e sob condicionamento osmótico, osmopriming. Os padrões de plantio foram semeadura a lance (broadcast) e em linha (row plantation) e quarto dosagens de herbicidas foram aplicadas (pyroxulam nas dosagens 14,08, 10,56, 7,04 e 7,521 g i.a. ha^{-1}), em um delineamento inteiramente casualizado em sistema de parcela subdividida split-plot. Os dados relativos à densidade de plantas daninhas, ao estabelecimento, ao crescimento e ao rendimento dos traços de trigo associados foram registrados e analisados por técnica de análise de variância usando software estatístico DSAASTAT. Os resultados revelaram que a contagem final de emergência foi significativamente melhorada pela semeadura em linha. Os tratamentos de

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preparação de sementes resultaram em emergência prévia de colheita e propagação do dossel e também diminuiu a densidade de ervas daninhas e o peso seco em 13% e 18%, respectivamente, a 60 DAS (dias após a semeadura). Além disso, o rendimento de grãos foi melhorado em 8% também nas parcelas de tratamento de cebola. A semeadura em linha do tratamento do trigo diminuiu a densidade de ervas daninhas e o peso seco em 17% e 25%, respectivamente, com um rendimento de grão melhorado em 14% em relação ao método de semeadura a lance. O Pyroxulam com uma taxa de 14,08 g i.a. ha^{-1} aplicado a 60 DAS reduziu a densidade total de ervas daninhas e o peso seco em 88% e 96%, respectivamente, e o rendimento de grãos foi melhorado em 36% em relação às parcelas de verificação de plantas daninhas. Em conclusão, as sementes sob condicionamento osmótico (1% de KCl) semeadas em linhas de 22,5 cm de distância proporcionaram maior produção de trigo, as ervas daninhas foram devidamente controladas por aplicação de piroxulam aplicado na dose recomendada (14,08 g i.a. ha^{-1}) e também 75% da dose recomendada sob condições de Faisalabad.

Palavras-chave: iniciação de sementes, geometria de plantação, herbicidas, espectro de ervas daninhas.

INTRODUCTION

Wheat is the most important grain crop, even among all crops, as a direct source of food for humans. In Pakistan, it occupies the first position among cereal crops (Noorka and Tabasum, 2013). The average yield of wheat crops does not exceed 30 to 35 percent of its potential yield in the country (Abbas et al., 2016). Thus, a yield gap exists between potential and actual yield that needs to be abridged through proper management practices (Noor, 2017).

Among factors that are affecting wheat productivity, the major reason for the low yield of wheat is weed infestation (Verma et al., 2015). It reduces wheat yields by 37-50% depending on the intensity of weeds (Waheed et al., 2009). Weeds reduce the quality of the produce, increase harvesting costs, clog waterways, and increased fire hazards (Noorka and Shahid, 2013). Weeds compete with crop plants for nutrients, water, light, space and provide shelter to pests, fungi and disease, favoring organisms through the release of allelo-chemicals in the root zone (Khaliq et al., 2013).

Mostly cultural, mechanical, and chemical methods are used to control weeds in wheat fields, with each method having its own pros and cons. Chemical means are used to control weeds as they allow quick, easy and economical solutions to a number of weed problems (Lagator, 2013). The efficacy of different herbicides varies according to crop management practices, and there is often a dose-dependent response of herbicides under varying agro-management practices (Agostinetto et al., 2016; Singh et al., 2016). Pyroxsulam (PALLAS™ 45 OD, Dow AgroSciences LLC.) is a comparatively new ALS-inhibiting (acetolactate synthase) herbicide registered for use in wheat in 2008. An herbicide will be highly efficient if the weed-index value is low. Pyroxsulam containing triazolopyrimidine provides broad spectrum post emergence annual grass and broadleaf weed control in cereals by inhibiting the action of ALS enzyme. Pyroxsulam's attributes of its superior toxicity and environmental-friendly profiles was made available commercially in 2008 (Gonzalea et al., 2008). Herbicide carryover phytotoxicity can be minimized with reduced rates of herbicide doses (Blackshaw et al., 2006).

Fast and uniform field emergence of crops are important factors for high returns in terms of both quantity and quality in the annual crops (Noor et al., 2016). To promote the pre-germination metabolic activities, seed priming is performed. Many invigoration methods have been studied for wheat (Lee and Kim, 2000), and KCl priming has also been recommended for early vigor in wheat (Khakwani et al., 2011).

Interference by weeds within a crop is strongly influenced by agronomic practices (i.e. sowing methods) (Olsen et al., 2005). In wheat, stand establishment is influenced by sowing methods (Amin et al., 2014). Drill sowing is a recommended planting method due to its' uniform seed distribution and planting depth, which usually results in higher germination stand. Over several years, the planting pattern/geometry of the wheat crop has been modified to increase yield, and line sowing has replaced broadcasting to a large extent (Das and Yaduraju, 2011).

The above discussion suggests that it is necessary for managing weeds in wheat crops for having good harvests. Priming can give a boost to the crop by early establishment (Bakhtavar et al., 2015; Ahmad et al., 2016). This warrants the need to optimize the herbicide dose for effective weed control in wheat sown by different methods. This present study aims to assess the levels of weed suppression by reduced herbicide doses.

MATERIALS AND METHODS

A field experiment was conducted at the Agronomic Research Farm, Department of Agronomy, University of Agriculture, Faisalabad, Pakistan during the winter wheat growing season 2013-14. The experiment was laid out in a randomized complete block design (RCBD) with split-split plot arrangement replicated thrice having net plot size of 5.0 m x 2.7 m. A wheat cultivar 'Punjab-2011' (Parentage: Amsel/Attila//Inqlab/Pew "s") was sown on 4 December, 2013 using a seed rate of 125 kg ha^{-1}. Fertilizer (NPK) was applied at the rate of 100: 55: 45 kg ha^{-1}. Metrological data collected during the whole crop season revealed the average monthly temperature was 17.41 ^{o}C, 7.15 sunshine hours per month, 14 mm average rainfall in last three months and 60.33% average relative humidity. The experimental soil was loamy soil containing 0.62% organic matter, 0.0434% total nitrogen, available phosphorus 9.83 mg kg^{-1}, available potassium 125 mg kg^{-1}, with 7.56 soil pH and 1.79 dS m^{-1} ECe.

Treatments

During the experiment, osmoprimed and non-primed seeds were used for sowing. Broadcast and line sowing (22.5 cm apart rows) methods were used for crop sowing. Four doses of herbicide were applied during the experiment; Pyroxulam (PALLAS™ 45 OD [a.i. Triazolopyrimidine; 45 g L^{-1}]) at the rate of 14.085 g a.i. ha^{-1}, 10.56 g a.i. ha^{-1}, 7.04 g a.i. ha^{-1} and 3.521 g a.i. ha^{-1}. For osmopriming, wheat seed was soaked in an aerated solution of KCl for 24 h, and the seed to solution ratio was 1:5 (w/v). After soaking, seeds were dried in the shade until their original weight was attained (Ahmad et al., 2016). The volume of spray (320 L ha^{-1}) was calibrated using water prior to treatment application. In weed free treatment, weeds were controlled manually and in weedy check, no herbicide was applied and weeds were allowed to compete throughout the season.

During this study, data regarding weeds (weed density and weed dry biomass), growth (emergence count, leaf area indices at fortnight intervals, fresh and dry biomass of crop at fortnight interval) and yield attributes (plant height at maturity, number of productive tillers, number of spikelet per spike, number of grains per spike, 1000 grain weight, biological yield, grain yield and harvest index) were recorded (Afzal et al., 2015). In order to record weed density, a quadrate (measuring 0.25 m^{-2}) was randomly placed in each plot two times (60 DAS and 90 DAS), and the average was computed. For measuring weed biomass, individual weeds from each quadrate were put in paper bags and fresh weight was recorded. After sun drying, these were placed in an oven at 70 ^{o}C until constant weight was achieved. For measuring the leaf area, a randomly selected area of 25 cm x 25 cm was harvested at ground level from each plot at 15 days intervals up to 105 DAS, was analyzed for leaf area and afterward dry matter accumulation was also calculated. The leaf area index (LAI) was calculated as the ratio of leaf area to ground surface area.

$$LAI = \frac{Leaf\ area}{Land\ area}$$

Crop growth rate was determined at 15 days interval using formula:

$$CGR = \frac{W_2 - W_1}{t_2 - t_1}$$

where W_1, total dry matter at the first harvest; W_2, total dry matter at the second harvest; t_1, date of observation of first dry matter; t_2, date of observation of second dry matter.

The wheat crop was harvested from the whole plot at harvest maturity, tied in bundles and sun dried for 5 days in the field. The total weight of sun-dried samples was recorded and converted into kg ha^{-1}. The dried samples of each plot were threshed manually. After threshing, the wheat grain yield was weighed at 12% moisture level and converted into kg ha^{-1}.

Statistical analysis

Data collected on growth and yield of crop was analyzed statistically by using Fisher's analysis of variance technique and the treatment's mean was compared by using the least significant difference test (LSD) at 5% probability level (Steel et al., 1997).

RESULTS AND DISCUSSION

Weeds related parameters

The data regarding total weed density at 60 DAS (Table 1) revealed that it varied significantly *($p\leq0.05$)* under the interactive influence of seed pre-treatment, planting geometry and weed control treatments. Statistically similar and higher total weed density was recorded in weedy check plots sown with non-primed seed in both planting geometries and high density was observed when primed seeds were sown by the broadcast method, whereas 44% less weed density was recorded in line sowing with primed seed (Table 1). The application of recommended dose of pyroxsulam recorded minimum number of weeds (52-74% less as compared to weedy check). Statistically ($p\leq0.05$) similar reduction (58%) in weeds was observed when a reduced dose of pyroxsulam (75% of recommended dose) was applied to non-primed seeds (Table 1). The data regarding total weed density recorded at 90 DAS revealed that the maximum suppression was obtained in line sowing with seed priming (Table 1). Statistically similar and higher total weed density was recorded in weedy check plots sown by the broadcast method with both seed pre-treatments, whereas 19-35% less weed density was recorded in line sowing under both seed pre-treatments.

Table 1 - Influence of seed pre-treatment, planting geometry and weed control treatments on total weed density (W.D.) (0.25 m^2) and total weed biomass (W.B.) (g 0.25 m^2) in wheat at 60 and 90 DAS

Seed pre-treatment (S)	W.D. at 60 DAS	W.D. at 90 DAS	W.B. at 60 DAS	W.B. at 90 DAS
No Priming	12.78 A	11.07	3.68 A	11.02
KCl Priming	11.08 B	10.10	3.03 B	10.27
HSD (honest significant difference) ($p\leq0.05$)	1.40	NS	0.11	NS
Planting geometry (P)				
Broadcast	13.25 A	11.95 A	3.84 A	12.10 A
Line sowing	10.62 B	9.22 B	2.88 B	09.19 B
HSD ($p\leq0.05$)	0.98	0.95	0.16	0.90
Weed control treatments (W)				
Weedy check	21.63 A	25.83 A	7.90 A	27.24 A
Weed free (three hand weeding)	-	-	-	-
Pyroxsulam (recommended dose)	2.54 E	1.96 D	0.35 D	1.67 D
Pyroxsulam (75% of recommended dose)	5.75 D	3.58 D	1.02 D	3.01 D
Pyroxsulam (50% of recommended dose)	11.42 C	7.92 C	2.81 C	6.10 C
Pyroxsulam (25% of recommended dose)	18.33 B	13.63 B	4.72 B	14.31 B
HSD ($p\leq0.05$)	2.09	2.09	0.70	2.17
S × P	2.58	2.63	0.29	3.30
S × W	4.01	3.90	1.06	4.82
P × W	3.60	3.37	1.08	3.62
S × P × W	6.78	5.91	1.86	5.78

The total weed biomass at 60 DAS was significantly affected by seed pre-treatments, planting geometry and weed control treatments. Minimum and statistically similar weed dry biomass was recorded in weedy check plots under line sowing with both primed and non-primed seeds (Table 1). The maximum reduction in total weed biomass was recorded when recommended dose of pyroxsulam was applied which was statistically similar to reduced dose application (75% of recommended dose). Data pertaining to total weed biomass at 90 DAS showed that 36% less weed density was recorded in line sowing method sown with primed seed. Application of recommended dose of pyroxsulam recorded minimum total weed biomass (92-96% less as compared to weedy check) regardless of seed pre-treatments and planting geometries.

The data regarding density of *C. arvensis* at 60 DAS revealed that minimum weed density (20%) was recorded in weedy check plots sown with primed seed, which was statistically similar to non-primed seeds and with 25% of recommended dose application of pyroxsulam with non-primed seeds. With primed and non-primed seeds treatments, maximum reduction in weed density was noted where pyroxsulam at recommended dose was applied which was statistically similar to plots sown with primed seeds where 75% of recommended doserecommended dose of pyroxsulam was applied (Table 2). Data pertaining to density of *C. didymus*, *R. dentatus* and *M. indica* showed that there was no significant (*p≤0.05*) influence of seed pre-treatments and planting geometries. In case of *C. didymus*, maximum suppression (91%) was recorded with pyroxsulam at recommended doserecommended dose at 60 DAS (Table 2). In case of *R. dentatus* recommended dose of pyroxsulam and 75% of recommended dose gave maximum (90% and 75%, respectively) suppression of this weed's density. The interaction of seed pre-treatment and weed control treatments was non-significant.

Growth attributes

The data (Table 3) showed that final emergence was not significantly (*p≤0.05*) affected by seed pre-treatment. However, planting geometry showed significant effects, and in line sowing 205 plants m^{-2} were recorded as compared with broadcasting (174 plants m^{-2}). Size of assimilatory system of a crop is indicated by its leaf area index. Extent of development of leaf area indices

Table 2 - Influence of seed pre-treatment, planting geometry and weed control treatments on density of *Convolvulus arvensis*, *Coronopus didymus*, *Rumex dentatus* and *Melilotus indica* (0.25 m^2) in wheat at 60 DAS

Seed pre-treatment (S)	*Convolvulus arvensis*	*Coronopus didymus.*	*Rumex dentatus*	*Melilotus indica*
No Priming	4.75	2.82	3.22	1.78
KCl Priming	4.05	2.43	3.38	1.60
HSD (honest significant difference) (p≤0.05)	NS	NS	NS	NS
Planting geometry (P)				
Broadcast	4.57	2.77	3.60	2.15
Line sowing	4.23	2.48	3.00	1.23
HSD (p≤0.05)	NS	NS	NS	NS
Weed control treatments (W)				
Weedy check	7.71 A	4.63 a	6.13 A	3.58 A
Weed free (three hand weeding)	------	------	------	------
Pyroxsulam (recommended dose)	1.04 E	0.42 d	0.63 C	0.54 B
Pyroxsulam (75% of recommended dose)	2.67 D	1.71 c	1.54 C	0.75 B
Pyroxsulam (50% of recommended dose)	4.58 C	2.71 bc	2.88 B	0.96 B
Pyroxsulam (25% of recommended dose)	6.00 B	3.67 ab	5.33 A	2.63 A
HSD (p≤0.05)	1.31	1.15	1.208	1.65
S x P	NS	NS	NS	NS
S x W	2.93	NS	NS	NS
P x W	2.27	NS	NS	2.73
S x P x W	NS	NS	NS	NS

Table 3 - Influence of seed pre-treatment, planting geometry and weed control treatments on final emergence count (m^2), leaf area duration (LAD), Plant height (cm), No. of productive tillers and No. of spikelet's per spike of wheat

Seed pre-treatment (S)	Emergence count	LAD	Plant height	Productive tillers	Spikelets/spike
No Priming	187	287 B	96.30 B	247.94 B	17.364
KCl Priming	192	324 A	99.56 A	260.25 A	17.736
HSD (honest significant difference) ($p \leq 0.05$)	NS	14.48	0.41	11.84	NS
Planting geometry (P)					
Broadcast	174 B	294 B	94.00 B	240.94 B	16.50 B
Line sowing	205 A	318 A	101.86 A	267.25 A	18.60 A
HSD ($p \leq 0.05$)	23	17.50	4.47	15.30	0.66
Weed control treatments (W)					
Weedy check	187	256 D	96.60	228.67 C	16.40 BC
Weed free (three hand weeding)	194	345 A	101.03	279.42 A	18.88 A
Pyroxsulam (recommended dose)	189	324 AB	94.83	267.92 AB	18.58 AB
Pyroxsulam (75% of recommended dose)	192	310 BC	98.99	252.92 ABC	18.14 ABC
Pyroxsulam (50% of recommended dose)	187	307 BC	98.49	249.58 BC	17.36 ABC
Pyroxsulam (25% of recommended dose)	188	294 C	97.63	246.08 BC	15.93 C
HSD ($p \leq 0.05$)	NS	23.28	NS	29.21	2.46
S × P	NS	36.22	NS	NS	NS
S × W	NS	NS	NS	NS	NS
P × W	NS	NS	NS	NS	NS
S × P × W	NS	NS	NS	NS	NS

varied significantly ($P \leq 0.05$) for both primed and non-primed seeds so that relatively higher LAI in KCl primed seeds was recorded as compared with the non-primed ones (Figure 1). Maximum leaf area index was noted in line sowing compared with broadcast sown with non-primed seeds. In plots sown with non-primed seeds, herbicide at recommended dose and weed free treatments gave maximum leaf area index at 3rd harvesting stage (75 DAS) in line sowing treatment. Results presented in Figure 2 indicates that with passage of time crop growth rate was increased but it was decreased after the maximum was achieved which was measured between 90-105 DAS. The crop growth rate was relatively higher in line sowing than the broadcast due to uniform crop stand establishment. The main effects of seed pre-treatment, planting geometry and weed control treatment on crop growth rate at 75 DAS of wheat were significant ($p \leq 0.05$). When pyroxsulam was applied at recommended dose to primed seeds, it recorded highest CGR in line sowing as compared with broadcasting. Minimum CGR was recorded for the broadcast sowing with non-primed seeds. Data regarding plant height (Table 3) showed significant ($p \leq 0.05$) influence of seed pre-treatments on plant height. Greater plant height was recorded for primed seeds (1% KCl) while lower was found for no priming. Line sowing resulted in 8% increase in plant height over broadcast sowing.

Yield related parameters

Data regarding all the yield related parameters of wheat were recorded and then analyzed statistically as given in Tables 3 and 4. Data pertaining to the number of productive tillers m^{-2} (Table 3) revealed that there was significant ($p \leq 0.05$) influence of KCl seed priming on productive tillers. KCl priming produced more productive tillers (260) than non-primed seeds (247). Line sowing resulted in an 11% increase in productive tillers than broadcast method. Weed free treatments gave maximum number of productive tillers which was statistically at par with treatments where pyroxsulam at its recommended dose was used. Minimum number of productive tillers were recorded in weedy check plots. Weed free treatments, pyroxsulam at recommended dose and 75% of recommended dose resulted in 22%, 17% and 11% higher number of productive tillers, respectively, as compared to weedy check.

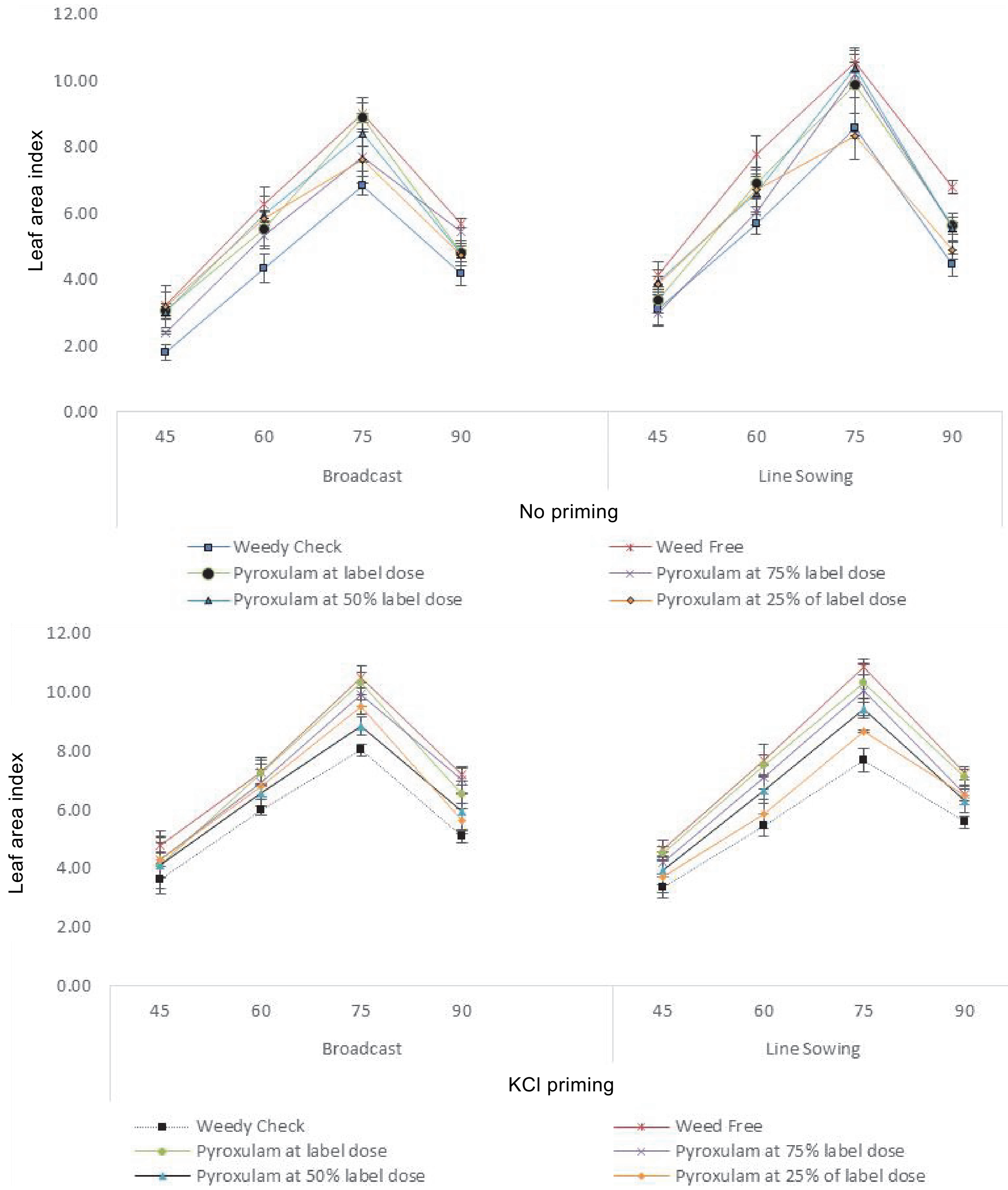

Figure 1 **-** Leaf area index of wheat as affected by seed pre-treatment, planting geometry and weed control treatments over time.

Data regarding the number of spikelets per spike revealed that, line sowing increased 13% spikelets per spike in wheat as compared to broadcasting (Table 3). Maximum (18.8) spikelets per spike were recorded in weed free plots which was statistically similar with herbicide doses (100%, 75% and 50% of recommended dose). Maximum number of grains per spike was noted from plots where pyroxsulam at its recommended dose was used which was similar with weed free and pyroxsulam at 75% treated plots (Table 4). A minimum number of grains per spike were recorded from weedy check plots which were statistically similar with pyroxsulam at 25% of

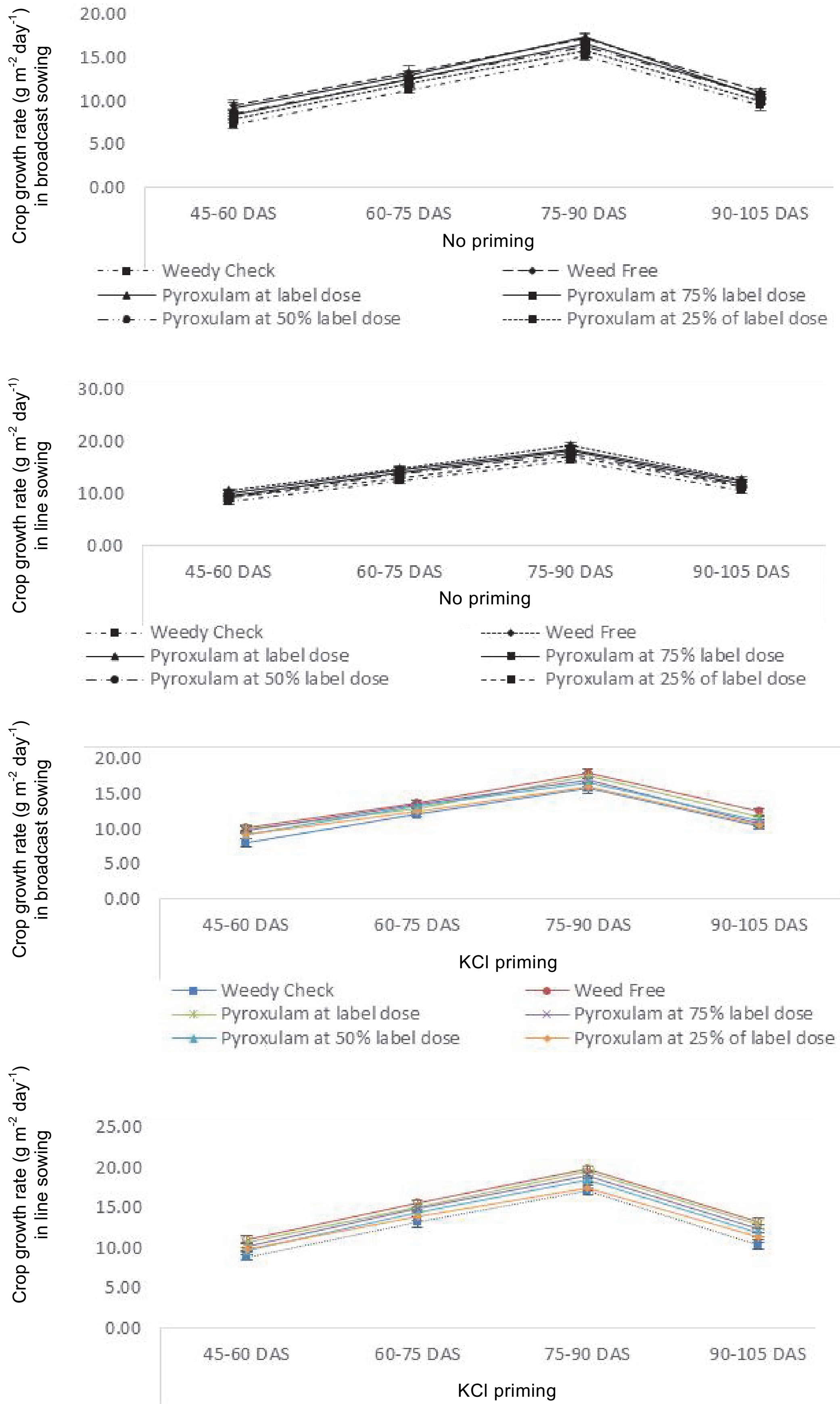

Figure 2 - Crop growth rate (g m^{-2} day^{-1}) of wheat as affected by seed pre-treatment, planting geometry and weed control treatments over time.

Table 4 **-** Influence of seed pre-treatment, planting geometry and weed control treatments on grains per spike, 1000 grain weight (g), biological yield (t ha^{-1}), grain yield (t ha^{-1}) and harvest index of wheat

Seed pre-treatment (S)	Grains/spike	1000 grain weight	Biological yield	Grain yield	Harvest index
No Priming	52.13 B	38.79	13.32 B	4.57 B	34.32
KCl Priming	55.67 A	38.84	14.38 A	5.07 A	35.50
HSD (honest significant difference) (p≤0.05)	3.31	NS	1.01	0.38	NS
Planting geometry (P)					
Broadcast	52.82 B	38.80	12.96 B	4.45 B	34.33
Line sowing	55.27 A	38.83	14.73 A	5.19 A	35.49
HSD (p≤0.05)	2.11	NS	1.36	0.15	NS
Weed control treatments (W)					
Weedy check	49.96 D	39.17 AB	11.73 D	3.95 D	33.66
Weed free (three hand weeding)	55.81 AB	39.01 AB	14.72 AB	5.43 A	37.17
Pyroxsulam (recommended dose)	57.10 A	39.46 AB	15.47 A	5.39 A	35.06
Pyroxsulam (75% of recommended dose)	55.65 ABC	39.74 A	14.43 ABC	5.04 AB	34.92
Pyroxsulam (50% of recommended dose)	55.28 BC	38.73 AB	13.77 BC	4.69 BC	34.53
Pyroxsulam (25% of recommended dose)	52.48 CD	37.78 B	12.96 CD	4.42 C	34.10
HSD (p≤ 0.05)	3.21	1.92	1.99	0.40	NS
S x P	NS	NS	3.30	0.31	NS
S x W	NS	NS	NS	NS	NS
P x W	NS	NS	NS	NS	NS
S x P x W	NS	NS	NS	NS	NS

recommended dose treated plots. The results indicated that seed pre-treatment and planting geometry showed non-significant effect for 1000-grain weight. Maximum 1000-grain weight was recorded from plots where pyroxsulam at 75% of recommended dose was applied. Minimum 1000 grain weight was recorded in plots where pyroxsulam at 25% of recommended dose was applied.

Data regarding biological yield (Table 4) revealed that it was significantly affected by seed pre-treatment, planting geometry as well as different herbicide doses. Weed free and herbicide (100% and 75% of recommended dose) gave 24%, 25% and 12% increase in biological yield over weedy check, respectively. Minimum biological yield was found for weedy check plots. Maximum grain yield was recorded in weed free and pyroxsulam at its recommended dose treated plots, which was 37% and 35% more over weedy check treatment. Reduced doses of pyroxsulam (75%, 50% and 25% of recommended dose) resulted in 28%, 19% and 12% increase in grain yield, respectively as compared with weedy check treatment. Harvest index was not significantly affected by seed pre-treatment and planting geometry, also there was no effect of weed control treatments (Table 4). The interaction between seed pre-treatment, planting geometry and weed control treatments was found non-significant.

Application of pyroxsulam proved very fruitful in controlling the weed density in present study. Amongst different pyroxsulam doses, the recommended dose resulted in more eradication of weeds as compared to its reduced doses. However, in case of planting geometries, 44% less weed density as compared to weedy check was recorded in line sowing with primed seed. For weed biomass, maximum biomass was observed in weedy check. Similarly, minimum biomass was shown by recommended dose and 75% reduced dose of pyroxsulam. Maximum dry biomass reduction in line sowing with KCl priming might be due to less space available to weeds for growth. These results are in confirmatory with the results of Whish et al. (2002) who reported that density and biomass of weeds increase with increase in space. Similar findings were presented by Zafar et al. (2012) who revealed that density and biomass of weeds increases as weed crop competition increases. Priming increased the competitive ability of crop to suppress the weeds (Juraimi et al., 2012).

KCl priming might lead to significant improvement in emergence. Line sowing improved final emergence count by 18% versus the broadcast method. These results are also supported by Singh et al., (2007) who reported that drilling produced better germination and higher values of growth than broadcast method. It was observed that for both the sowing methods, KCl priming developed higher LAI and the differences grew wider with the advancement in developmental stage of the crop. The decline in LAI following the flag leaf stage might be ascribed by aging of leaves, leaf senescence and thermal stress at later growth stages (Dalirie et al., 2010). Priming with KCl increased the plant height as compared to non-primed plants. Regarding planting geometries, 8% increase in plant height was found for line sowing, compared to broadcast.

As number of productive tillers were maximized in weed free treatment. An application of pyroxsulam at label and 75% reduced dose produced 17 and 11% more tillers as compared to weedy check. The results are in agreement with the work of Khan et al. (2003), who reported that there has been a significant increase in the number of tillers with the application of some herbicides in their studies. Sowing of plants using in line sowing significantly increased the spikelets per spike. However, weed free plants produced more spikelets which was statistically similar with herbicide doses. Cheema and Akhtar (2005) reported that herbicide application affects spikelets per spike over weedy check. Minimum grains per spike were produced in weedy check plots as weeds compete with crop plants. These results are further supported by Qasem et al. (2008) who reported that number of grains reduced significantly with increasing weed density.

Application of pyroxsulam at its recommended dose and 75% reduced dose significantly improved the grain yield and biological yield as compared to other treatments. These results confirm those of Khan et al. (2003), Tiwari et al. (2011) and Usman et al. (2013) who reported that herbicide increased biological and grain yield of wheat. However, during our study it was observed that harvest index was not affected because of herbicide doses. These results are in agreement with Nejad et al. (2013), who also revealed that there was no significant contribution of herbicides on harvest index of wheat.

In conclusion, the present study concluded that pyroxulam applied at the recommended dose and 75% of this dose to plots sown with primed seeds reduced weed burden and increased CGR, LAI, grain yield while including the net benefits of in line sowing. Wheat yields continued to decline as weeds were allowed to grow.

REFERENCES

Abbas T. et al. Identifying Optimum Herbicide Mixtures to Manage and Avoid Fenoxaprop-p-Ethyl Resistant *Phalaris minor* in Wheat. **Planta Daninha**. 2016;34:787-94.

Afzal I. et al. Improvement of spring maize performance through physical and physiological seed enhancements. **Seed Sci Technol.** 2015;43:238-49.

Ahmad W. et al. Improvement of sorghum crop through exogenous application of natural growth-promoting substances under a changing climate. **Sustainability**. 2016;8:1330.

Amin M. et al. Comparative study of different methods of wheat planting. **Int J Modern Agric.** 2014;3:123-26.

Agostinetto D. et al. Changes in photosynthesis and oxidative stress in wheat plants submitted to herbicides application. **Planta Daninha**. 2016;34:1-9.

Bakhtavar M.A. et al. Physiological strategies to improve the performance of spring maize (*Zea mays* L.) Planted under early and optimum sowing conditions. **PLoSONE**. 2015;10:e0124441.

Blackshaw R.E. et al. Reduced herbicide doses in field crops: A review. **Weed Biol Manage.** 2006;6:10-7.

Cheema M.S., Akhtar M. Efficacy of different post emergence herbicides and their application methods in controlling weeds in wheat. **Pak J Weed Sci Res.** 2005;11:23-9.

Dalirie M.S., Sharifi R.S., Farzaneh S. Evaluation of yield, dry matter accumulation and leaf area index in wheat genotypes as affected by terminal drought stress. **Not Bot Hortic Agrobot Cluj-Napoca**. 2010;38:182-6.

Das T.K., Yaduraju N.T. Effects of missing row sowing supplemented with row spacing and nitrogen on weed competition and growth and yield of wheat. **Crop Past Sci.** 2011;62:48-57.

Gonzalea M.A. et al. Process development for the sulfonamide herbicide pyroxsulam. **Org Proc Res Develope.** 2008;12:301-3.

Juraimi A.S. et al. Diversity of weed communities under different water regimes in irrigated direct seeded rice field. **Pak J Weed Sci Res.** 2012;18:257-64.

Khakwani A.A. et al. Early growth response of six wheat varieties under artificial osmotic stress condition. **Pak J Agric Sci.** 2011;48:121-6.

Khaliq A. et al. Aqueous swine cress (*Coronopus didymus*) extracts inhibit wheat germination and early seedling growth. **Int J Agric Biol.** 2013;15:743-748.

Khan M.I. et al. Efficacy of some new herbicidal molecules on weed density, yield and yield components of wheat. **Pak J Weed Sci Res.** 2003;9:141-6.

Lagator M. et al. Herbicide mixtures at high doses slow the evolution of resistance in experimentally evolving populations of *Chlamydomonas reinhardtii*. **New Phytol.** 2013;198:938-45.

Lee S.S., Kim J.H. Total sugars, a-amylase activity, and germination after priming of normal and aged rice seeds. **Korean J Crop Sci.** 2000;45:108-11.

Nejad A.Y. et al. Studying the effects of using herbicides and split of nitrogen fertilizer on yield and yield components of D79-15 wheat. **Int J Agric Crop Sci.** 2013;5:2473-80.

Noor, M. A. Nitrogen management and regulation for optimum NUE in maize – A mini review. **Cogent Food Agric**. 2017;3: 1348214.

Noor M.A. et al. Pea seed invigoration by priming with magnetized water and moringa leaf extract. **Philipp Agric Sci**. 2016;99:171-5.

Noorka I.R., Tabasum S. An empirical approach to get the vitality of a genotype to water stress tolerance in yield and yield contributing traits. **Am J Plant Sci.** 2013;5:999-1003.

Noorka I.R., Shahid S.A. **Use of conservation tillage system in semiarid region to ensure wheat food security in Pakistan**; development in soil salinity assessment and reclamation. London: Springer Book, 2013.

Olsen J. et al. Increased density and spatial uniformity increase weed suppression by spring wheat. **Weed Res.** 2005;45:316-21.

Qasem M. et al. Sowing date effect on yield and yield component of different wheat varieties. **J Agric Res.** 2008;46:135-40.

Singh K.K. et al. Tillage and planting management for improving the productivity and profitability of rice-wheat cropping system. **Agric Mech Asia**. 2007;38:72-6.

Singh R.P. et al. Effects of herbicides on growth and yield of *Cicer arietinum* L. under rainfed condition. **Bangladesh J Bot.** 2016;45:305-11.

Steel R.G.D. et al. **Principles and procedures of statistics, a biometrical approach**. 3rd. New York: McGraw Hill, 1997. p.352-8.

Tiwari R.K. et al. Effect of weed control treatments on growth of little seed canary grass and productivity of wheat. **Ind J Weed Sci.** 2011;43:239-43.

Usman K. et al. Integrated effect of tillage and herbcides on weed control and wheat yield in cotton based cropping system. **Sarhad J Agric.** 2013;29:495-501.

Verma S.K. et al. Influence of irrigation regimes and weed management practices on water use and nutrient uptake in wheat (*Triticum aestivum* L. Emend. Fiori and paol.). **Bangladesh J Bot.** 2015;44:437-42.

Waheed A. et al. Weed community dynamics in wheat crop of district Rahim Yar Khan, Pakistan. **Pak J Bot.** 2009;41:247-54.

Whish J.P.M. et al. The effect of row spacing and weed density on yield loss of chickpea. **Aust J Crop Sci.** 2002;53;1335-40.

Zafar M. et al. Effect of plant growth-promoting rhizobacteria on growth, nodulation and nutrient accumulation of lentil under controlled conditions. **Pedosphere.** 2012;22:848-59.