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Article

Efficacy Evaluation of Fertilizers and Weed Control Practices to Mitigate Wheat Nutrient and Yield Losses

Avaliação da Eficácia de Fertilizantes e Práticas de Controle de Plantas Daninhas para Mitigar Perdas de Rendimento e Nutrientes do Trigo

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ABSTRACT - Low fertilizer use efficiency due to inappropriate weed control practices is one of the main causes of poor wheat yield worldwide. A 2 year field experiment was conducted to study the effects of three fertilizer levels and four weed control practices on fertilizer use efficiency and nutrient uptake by wheat and its associated weeds. Fertilizer levels were F_0 (zero fertilizer), F_1 (75 kg ha^{-1} N + 50 kg ha^{-1} P_2O_5), and F_2 (150 kg ha^{-1} N + 100 kg ha^{-1} P_2O_5) and weed control included W_1 (weedy check), W_2 (pendimethalin applied at 1,031 g a.i. ha^{-1}), W_3 (isoproturon + carfentrazone ethyl applied at 750 g a.i. ha^{-1}) and W_4 (manual weed control). Different weed control practices significantly reduced the NPK uptake by weeds and increased NPK uptake by wheat. Maximum uptake of NPK by wheat and minimum uptake by weeds were recorded in W_4. Increasing dose of fertilizer increased NPK uptake by both weeds and wheat. However maximum fertilizer use efficiency and grain yield of wheat were achieved when highest dose of fertilizers (F_2) was used along with manual weed control method (W_4), which was followed by F_2 and W_3 during both years. We have come to the conclusion that to achieve higher wheat yield by increasing fertilizer doses, farmers should take appropriate weed control measures.

Keywords: grain yield, herbicides, fertilizer use efficiency, nutrients uptake, losses by weeds.

RESUMO - A utilização pouco eficaz de fertilizantes devido a práticas inadequadas de controle de plantas daninhas é uma das principais causas do baixo rendimento do trigo em todo o mundo. Foi realizado um experimento de campo de dois anos para estudar os efeitos de três níveis de fertilizantes e quatro práticas de controle de plantas daninhas, bem como para verificar a eficiência do uso de fertilizantes e a absorção de nutrientes pelo trigo e plantas daninhas associadas. Os níveis de fertilizantes foram: F_0 (0), F_1 (75 kg ha^{-1} N + 50 kg ha^{-1} P_2O_5) e F_2 (150 kg ha^{-1} N + 100 kg ha^{-1} P_2O_5); e as práticas de controle de plantas daninhas foram: W_1 (verificação de plantas daninhas), W_2 (pendimethalin aplicado a 1.031 g i.a. ha^{-1}), W_3 (isoproturon + carfentrazone-ethyl aplicado a 750 g i.a. ha^{-1}) e W_4 (controle manual de plantas daninhas). As diferentes práticas de controle de plantas daninhas reduziram significativamente a absorção de NPK por elas e aumentaram a absorção de NPK pelo trigo. A absorção máxima de NPK pelo trigo e a absorção mínima pelas plantas daninhas foram registradas em W_4. O aumento da dose do fertilizante intensificou a absorção de NPK tanto pelas plantas daninhas quanto pelo trigo. No entanto, a melhor eficiência de uso de fertilizantes e o maior rendimento de grãos de trigo ocorreram quando foi aplicada a maior dose de

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fertilizantes (F_2) juntamente com a prática de controle manual de plantas daninhas (W_4), seguida por F_2 e W_3, durante os dois anos. Conclui-se que, para aumentar o rendimento do trigo com maiores doses de fertilizantes, os agricultores devem empregar práticas adequadas de controle de plantas daninhas.

Palavras-chave: rendimento de grãos, herbicidas, eficiência do uso de fertilizantes, absorção de nutrientes, perdas por plantas daninhas.

INTRODUCTION

Wheat (*Triticum aestivum*) is world's most widely grown crop, a staple food for most of the global population including Pakistan and it is paramount to ensure global food security. It contributes with 10% of the value added in agriculture and 2.1% of gross domestic product in the country. In 2014-15, wheat was sown on an area of 9.2 million hectares with a total production of 25.5 million tons (Govt. of Pakistan, 2014-15). The average yield of wheat in Pakistan is about 60 to 65% less than its potential yield. Among various factors associated with low yield weed infestation, loss of nutrients caused by weeds and improper use of fertilizers are of supreme importance.

Common weeds associated with wheat in Pakistan are Melilotus alba, Convolvulus arvesis, Phalaris minor, Chenopodium album, Avena fatua, Rumex dentatus, Coronopus didymus, Anagalis arvensis, Fumeria indic and Medicago denticulate (Cheema et al., 2002; Tanveer and Ali, 2003; Khan et al., 2004). Weeds may cause 7-96% loss in wheat yield every year (Cheema et al., 2002; Tanveer and Ali, 2003; Nadeem et al., 2006). It is extremely hard to control grasses in wheat crops without using herbicides, due to their morphological similarities during the whole season until maturity with wheat crop and their severe infestation that causes up to 80% of yield losses (Rammoorthy and Subbain, 2006; Walia, 2006).

Nitrogen and phosphorus use efficiency in Pakistan are 40-50% and 15-20%, respectively (Rehim et al., 2012). Weed-crop competition is one of the main reasons for lower nutrient use efficiency, which ultimately leads to lower grain yield and increasedcost of production. Weeds compete with wheat and can deprive the crop of approximately 47% nitrogen, 42% phosphorus and 50% potash (Kumar and Singh, 1998). Studies on mineral fertilizers have shown increased crop yield and a simultaneous increase in the number or dry weight of weeds (Blackshaw et al., 2003). However, increase in fertilizer rate greatly improved the uptake of nitrogen (Blackshaw and Brandt, 2008), phosphorus (Blackshaw et al., 2004) and potash (Yadav et al., 1995) by weeds as compared to wheat crop (Blackshaw et al., 2003). Crop-weed mixture showed improved biomass and nutrients uptake by crops as compared to monoculture with limiting inorganic nutrients availability (Poffenbarger et al., 2015), showing that weed-crop proportion greatly influenced competition for nutrient uptake. Competitive ability of less nutrient-responsive weeds species with wheat was not affected by increased nutrient rate, regardless of highly nutrient-responsive weed species, which become more completive with wheat crop (Blackshaw et al., 2008). Fertilizer use efficiency is largely affected by changing application method, source, time and rate of fertilizer in weeds infesting a field of wheat, but have very little effect in weed-free fields (Blackshaw et al., 2005; Blackshaw and Molnar, 2009). Thus, weeds are a major factor to reduce fertilizer use efficiency and grain yield of wheat.

Therefore, the efficiency of nutrients could not be improved without appropriate weed control strategies considering type and intensity of weeds in wheat fields. The use of herbicides not only reduces weed density, but also increases nutrient uptake by wheat and reduces nutrient losses due to weeds (Walia et al., 2000; Safdar et al., 2011; Bharat et al., 2012). Reduced nutrient uptake by weeds as a result of weed control has also been reported by other researchers (Safdar et al., 2011; Bharat et al., 2012). Increased fertilizer use efficiency and wheat yield have been reported with the application of nitrogen and herbicides (Bazuglov and Gafurov, 2002; Sheibani and Ghadiri, 2011). Therefore, this study has been conducted to analyze how fertilizer rates may interact with weed control practices. The objective of this present experiment was to assess the losses caused by weeds at varying fertilizer levels and to determine proper weed control practices to increase fertilizer use efficiency in wheat.

MATERIALS AND METHODS

This research has been conducted at the Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan during 2013-14 and 2014-15. The experiment was conducted on sandy clay loam soil with 0.84 and 0.83% organic matter, 6.7 and 6.3 ppm phosphorus, 190 and 193 ppm potash and pH of 8.0 and 8.1 during 2013-14 and 2014-15, respectively. The experiment was comprised of three fertilizer levels i.e. $F_{1:}$ control (zero fertilizer), F_2 :75 kg ha^{-1} N + 50 kg ha^{-1} P_2O_5 and F_3: 150 kg ha^{-1} N + 100 kg ha^{-1} P_2O_5 and four weed control practices viz., W_1: weedy check, $W_{2:}$ pendimethalin applied at the rate of 1,031 g a.i. ha^{-1} (pre- emergence), W_3: isoproturon + carfentrazone ethyl applied at the rate of 750 g a.i. ha^{-1} (post- emergence) and W_4: manual weed control (consisting of two hoeing). The experiment was laid out in a randomized complete block design with split plot arrangement including three replications. Fertilizer levels, which were less important, were randomized in main plots and weed management practices, which were more relevant, were randomized in sub-plots. The sub-plot net size was 1.5 x 6.0 m. The crop was sown manually in rows 25 cm apart using a single row hand drill with a seed rate of 125 kg ha^{-1}.

Nitrogen and phosphorus as per treatment were applied in the form of urea and diammonium phosphate (DAP), respectively. All phosphorus and half nitrogen were applied at sowing time with a single row hand drill 5 cm away from the seed row and the remaining half of nitrogen was top dressed manually at tillering to coincide with the first irrigation (18 days after emergence). Pre-emergence herbicide was sprayed immediately after sowing the crop, whereas the post-emergence herbicide was sprayed after the first irrigation, when soil was at field capacity (28 days after sowing) and weeds were at the 2-3 leaf stage. Both herbicides were sprayed with a knapsack hand sprayer fitted with a flat fan nozzle. Water was calibrated and used at the rate of 300 L ha^{-1}. In manual weed control treatment, both hoeing were made at 20 and 40 days after sowing with a manual hoe.

Oven dried samples of weeds and wheat taken from one square meter area in each plot were ground and N, P and K contents were determined as suggested by Tecator (1991), Cottenie et al. (1979) and Williams (1984), respectively. Nitrogen, P and K percentage in weeds and wheat were multiplied with their respective dry weights to determine N, P and K uptakes. Fertilizer use efficiency (kg kg^{-1}) was calculated by using the formula of Barber (1976).

$$\text{Fertilizer use efficiency} = \frac{\text{Grain yield of fertilized plot - Grain yield of control}}{\text{Amount of fertilizer applied}}$$

Data collected was analyzed by using the Fisher's analysis of variance function of "MSTATC" statistical computer program. Least significant difference (LSD) at 5% probability was applied to compare treatments' means (Steel et al., 1997).

RESULTS AND DISCUSSION

Nutrient uptake by different weeds (kg ha^{-1}) at harvest

Different weed control practices significantly affected the nitrogen, phosphorus and potash uptake by *P. minor*, *A. fatua*, *C. album*, *C. murale* and *C. arvensis* (Tables 1-3). The interaction between weed control practices and fertilizer levels was also significant for nitrogen, phosphorus and potash uptake for all weeds in both the years. The significantly maximum NPK uptake by weeds was recorded in weedy check at 150 kg N + 100 kg P_2O_5 ha^{-1} (W_1 x F_2) against the minimum in manual hoeing without fertilizer application (W_4 x F_0). However, *C. murale* resulted in minimum nitrogen uptake with manual hoeing and application of 75 kg N + 50 kg P_2O_5 ha^{-1} (W_4 x F_1), which was statistically similar to manual hoeing without fertilizer application (W_4 x F_0).

The differences between pre-emergence application of pendimethalin (W_2) and post-emergence application of isoproturon + carfentrazone ethyl (W_3) for nitrogen uptake were

Table 1 **-** Effect of weed control practices and fertilizer levels on nitrogen uptake (kg ha^{-1}) by weeds at harvest

Weed control practices	*Phalaris minor*		*Avena fatua*		*Chenopodium album*		*Chenopodium murale*		*Convolvulus arvensis*	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
W_1 x F_0	12.25 de	14.78 c	2.51 e	3.89 c	7.75 c	6.20 c	1.26 c	2.30 c	1.13 b	1.14 b
W_2 x F_0	4.56 g	3.29 gh	0.99 gh	0.66 .i	1.78 gh	1.24 h	0.17 g	0.21 g	0.00 e	0.00 e
W_3 x F_0	5.54 g	3.90 gh	1.45 f	1.07 h	2.35 fg	2.68 g	0.17 g	0.51 ef	0.00 e	0.00 e
W_4 x F_0	1.36 i	0.99 i	0.84 h	0.46 i	0.73 i	0.71 h	0.16 g	0.12 g	0.00 e	0.00 e
W_1 x F_1	24.64 b	26.95 b	6.44 b	6.35 b	12.61 b	10.30 b	3.44 b	4.21 b	0.41 d	0.68 c
W_2 x F_1	10.74 ef	8.26 de	2.56 e	2.12 f	3.16 f	4.13 e	0.66 e	1.05 d	0.57 c	0.50 d
W_3 x F_1	9.35 f	6.59 ef	3.57 d	1.99 f	3.04 f	3.30 f	0.37 fg	0.45 f	0.00 e	0.00 e
W_4 x F_1	2.92 h	2.26 hi	1.27 fg	0.55 i	1.21 hi	1.29 h	0.14 g	0.15 g	0.00 e	0.00 e
W_1 x F_2	44.06 a	46.54 a	9.10 a	12.14 a	26.73 a	25.55 a	6.56 a	6.66 a	2.11 a	2.09 a
W_2 x F_2	13.59 cd	13.90 c	5.98 c	3.56 cd	6.28 d	5.89 c	0.61 ef	0.65 e	0.00 e	0.00 e
W_3 x F_2	14.92 c	10.10 d	3.73 d	2.79 e	4.67 e	4.87 d	0.92 d	0.92 d	0.61 c	0.66 c
W_4 x F_2	5.66 g	4.64fg	2.54 e	1.40 g	2.27 fg	3.15 fg	0.37 fg	0.40 f	0.00 e	0.00 e
LSD 5%	1.547	2.016	0.3163	0.287	0.969	0.582	0.249	0.163	0.077	0.054

Any two means not sharing a letter in common differ statistically at 5% probability level.

Table 2 **-** Effect of weed control practices and fertilizer levels on phosphorus uptake (kg ha^{-1}) by weeds at harvest

Weed control practices	*Phalaris minor*		*Avena fatua*		*Chenopodium album*		*Chenopodium murale*		*Convolvulus arvensis*	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
W_1 x F_0	3.54 c	4.09 c	0.66 d	0.96 c	1.71 c	1.29 c	0.33 c	0.61 c	0.38 b	0.39 b
W_2 x F_0	0.93 fg	0.71 hi	0.22 i	0.15 g	0.45 gh	0.29 h	0.03 g	0.05 g	0.00 f	0.00 e
W_3 x F_0	1.16 f	0.96 g	0.30 h	0.25 f	0.34 h	0.46 g	0.03 g	0.09 f	0.00 f	0.00 e
W_4 x F_0	0.58 h	0.46 j	0.29 h	0.18 g	0.31 h	0.31 h	0.04 g	0.03 g	0.00 f	0.00 e
W_1 x F_1	5.24 b	5.05 b	1.07 b	1.16 b	2.53 b	1.77 b	0.64 b	0.72 b	0.17 d	0.15 c
W_2 x F_1	2.27 e	1.59 ef	0.44 g	0.36 e	0.60 fg	0.62 f	0.14 e	0.20 d	0.21 c	0.14 c
W_3 x F_1	2.06 e	1.45 f	0.59 e	0.33 e	0.58 fg	0.63 f	0.08 f	0.10 f	0.00 f	0.00 e
W_4 x F_1	0.64 gh	0.66 ij	0.28 h	0.16 g	0.37 h	0.36h	0.04 g	0.04 g	0.00 f	0.00 e
W_1 x F_2	8.40 a	8.32 a	1.42 a	1.68 a	4.23 a	4.19 a	0.99 a	1.02 a	0.50 a	0.46 a
W_2 x F_2	2.32 e	2.17 d	0.95 c	0.51 d	1.12 d	1.05 d	0.09 f	0.09 f	0.00 f	0.00 e
W_3 x F_2	2.92 d	1.79e	0.71 d	0.48 d	0.86 e	0.84 e	0.18 d	0.17 e	0.13 e	0.12 d
W_4 x F_2	1.11 f	0.89 gh	0.49 f	0.26 f	0.65 f	0.61 f	0.06 fg	0.07 f	0.00 f	0.00 e
LSD 5%	0.302	0.210	0.0543	0.043	0.153	0.094	0.042	0.027	0.0196	0.014

Any two means not sharing a letter in common differ statistically at 5% probability level

Table 3 **-** Effect of weed control practices and fertilizer levels on potassium uptake (kg ha^{-1}) by weeds at harvest

Weed control practices	*Phalaris minor*		*Avena fatua*		*Chenopodium album*		*Chenopodium murale*		*Convolvulus arvensis*	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
W_1 x F_0	16.27 c	18.31 c	2.83 b	4.09 c	7.49 c	5.58 c	1.48 c	2.44 b	1.69 b	1.79 a
W_2 x F_0	2.96 fg	2.29 fg	0.64 h	0.45 f	1.27 efg	0.91 gh	0.14 e	0.17 f	0.00 f	0.00 f
W_3 x F_0	3.32 f	2.60 f	0.91 g	0.77 e	0.83 gh	0.14 fg	0.12 e	0.32 e	0.00 f	0.00 f
W_4 x F_0	1.95 g	1.34 g	0.77 gh	0.49 f	0.72 h	0.70 h	0.14 e	0.10 f	0.00 f	0.00 f
W_1 x F_1	22.98 b	14.23 b	4.56 a	4.96 b	10.14 b	7.48 b	3.12 b	3.69 a	0.68 d	0.67 c
W_2 x F_1	7.16 de	5.17 e	1.57 e	1.36 d	1.86 d	2.21 d	0.54 d	0.86 c	0.79 c	0.59 d
W_3 x F_1	7.48 d	5.50 de	1.78 d	1.29 d	1.76 de	2.08 de	0.23 e	0.37 e	0.00 f	0.00 f
W_4 x F_1	2.33 fg	2.13 fg	0.79 gh	0.56 f	1.02 gh	2.16 d	0.11 e	0.11 f	0.00 f	0.00 f
W_1 x F_2	26.52 a	27.43 a	4.57 a	6.09 a	11.42 a	12.03 a	4.04 a	3.70 a	1.89 a	1.72 b
W_2 x F_2	9.25 e	6.37 d	2.23 c	1.39d	0.00 i	2.43 d	0.20 e	0.29 e	0.00 f	0.00 f
W_3 x F_2	7.31 d	4.80 e	1.34 f	1.31 d	1.56 def	1.75 e	0.49 d	0.51 d	0.43 e	0.48 e
W_4 x F_2	2.41 fg	2.16 fg	0.89 g	0.53 f	1.18 fgh	1.33 f	0.13 e	0.15 f	0.00 f	0.00 f
LSD 5%	1.053	1.094	0.179	0.172	0.485	0.356	0.163	0.109	0.076	0.543

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non-significant at all fertilizer levels in both years for both grasses except at 150 kg N + 100 kg P_2O_5 ha^{-1} (F_2) for *P. minor* and at 75 kg N + 50 kg P_2O_5 ha^{-1} (F_1) for *A. fatua* in 2003-04. The post-emergence application of isoproturon + carfentrazone ethyl (W_3) resulted in significantly lower nitrogen uptake than pre-emergence application of pendimethalin (W_2) and this was observed at all fertilizer levels for *C. album* and *C. murale* in 2014-15. Application of pendimethalin as a pre-emergence treatment (W_2) resulted in significantly higher nitrogen uptake at all fertilizer levels, except for the control, to which no fertilizer was applied (F_0) in 2013-14, and at all fertilizer levels in 2014-15.

The differences between pre-emergence application of pendimethalin (W_2) and post-emergence application of isoproturon + carfentrazone ethyl (W_3) for phosphorus and potash uptake by weeds were significant at all fertilizer levels for *A. fatua,* but only with 150 kg N + 100 kg P_2O_5 ha^{-1} for *P. minor* and *C. album* and *C. arvensis* in 20-03, however both herbicides differed significantly at all levels except for 100 kg N + 75 kg P_2O_5 ha^{-1} narrow-leaved weeds in the second year. *C. murale* resulted in significant between two herbicidal treatments in both years, except for control in 2013-14.

Nitrogen, phosphorus and potash uptakes by different weed species decreased with the application of a weed control treatment over weedy check in both years. This could be due to decreased weed density and weed dry weight. These results are in accordance with the findings of Safdar et al. (2011) and Bharat et al. (2012) who have also reported a significant reduction in the uptake of NPK by weeds. However, lack of nitrogen, phosphorus and potash uptake by *C. arvensis* in the manual hoeing could be associated with complete extermination of this weed in this treatment.

Total nutrient uptake by weeds

Different weed control practices have significantly affected total nitrogen, phosphorus and potash uptake by weeds in both years (Figure 1). There was no significant year effect for total nutrient uptake by weeds, therefore, data were pooled before statistical analysis. The interaction between weed control practices and fertilizer levels for total nitrogen, phosphorus and potash uptake was significant in both years. Total NPK uptake by weeds was significantly greater in the in weedy check at 150 kg N + 100 kg P_2O_5 ha^{-1} (W_1 x F_2), followed by the same treatment at 75 kg N + 50 kg P_2O_5 ha^{-1} (W_1 x F_1) in both years. The minimum NPK uptake by weeds was recorded in the manual hoeing treatment at 0 kg N + 0 kg P_2O_5 ha^{-1} (W_4 x F_0). Pre-emergence application of pendimethalin (W_2) and post-emergence application of isoproturon + carfentrazone ethyl (W_3), showed the non-significant difference in total nitrogen, phosphorus and potash uptake during both years except potash at 150 kg N + 100 kg P_2O_5 ha^{-1}.

There was a linear increase in nitrogen and phosphorus uptake by weeds with an increase in fertilizer level. This increase could be attributed to the greater availability of nitrogen and phosphorus, resulting in better growth of weeds and greater nitrogen and phosphorus concentration (data not given). The significant increase in nitrogen uptake by weeds with increased nitrogen application has been previously reported by Blackshaw et al. (2008). However, in the case of *C. arvensis,* application of fertilizer could not increase the K uptake. This variation in results might be due to its lower dry weight at 75 kg N + 50 kg P_2O_5 ha^{-1}.

Nutrient uptake by wheat at harvest (kg ha^{-1})

Nitrogen and phosphorus uptake by wheat was significantly affected by different weed control practices and fertilizer levels (Table 4). Nitrogen and phosphorus uptake by wheat was significantly greater with manual weed control (W_4), in contrast with minimum nitrogen uptake, which in both years, was found for weedy check (W_1). Nitrogen and phosphorus uptake by wheat increased significantly with each increased fertilizer level.

The interaction between weed control practices and fertilizer levels was significant in both years. In 2013-14 maximum nitrogen and phosphorus uptake by wheat (102.10 and 26.25 kg ha^{-1}) were significantly greater with the manual hoeing and with the application of 150 kg N + 100 kg P_2O_5 ha^{-1} (W_4 x F_2). This was followed by post-emergence application of Isoproturon +

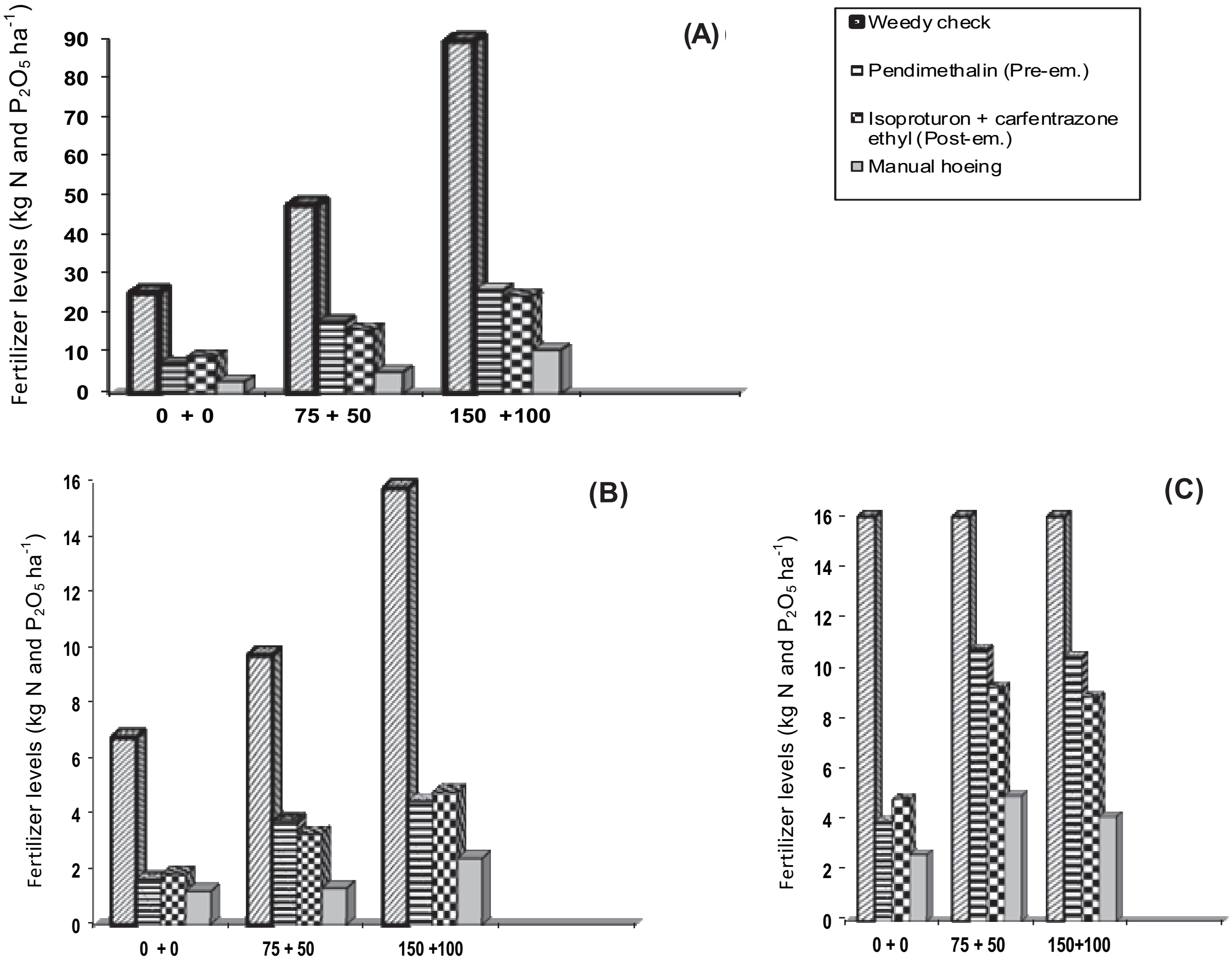

Figure 1 - Effect of fertilizer levels and weed control methods on (A) nitrogen, (B) phosphorus, and (C) potash uptake by weeds.

Table 4 - Effect of weed control practices and fertilizer levels on nutrient uptake (kg ha^{-1}), fertilizer use efficiency and grain yield of wheat

Weed control practices	N uptake (kg ha^{-1})		P-Uptake (kg ha^{-1})		K-uptake (kg ha^{-1})		Fertilizer use efficiency (kg kg^{-1})		Grain yield (kg ha^{-1})	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
W_1 x F_0	12.08 j	15.54 i	4.53 k	5.92 j	NS	NS	-	-	3865 k	3568
W_2 x F_0	18.92 i	17.10 i	5.63 j	6.84 i			-	-	4065 j	3856
W_3 x F_0	19.90 hi	17.56 i	6.16 ij	7.28 i			-	-	4365 i	3965
W_4 x F_0	22.46 h	25.48 h	6.65 i	8.32 h			-	-	4586 h	4089
W_1 x F_1	40.70 g	39.41 g	8.46 h	8.73 h			8.22 d	7.98 d	4892 g	4566
W_2 x F_1	49.70 f	49.97 f	11.20 g	12.28 g			9.60 c	8.08 d	5298 f	4866
W_3 x F_1	55.50 e	52.77 f	12.18 f	13.05 f			8.53 d	8.11 d	5432 f	4978
W_4 x F_1	60.88 d	56.84 e	14.7 e	14.21 e			8.10 d	1.81 d	5598 e	5065
W_1 x F_2	89.43 c	82.22 d	17.39 d	15.89 d			15.05 b	11.69 c	6133 d	5322
W_2 x F_2	92.50 b	91.38 c	22.86 c	20.82 c			17.91 a	12.95 b	6752 c	5798
W_3 x F_2	93.80 b	95.74 b	24.33 b	22.31 b			17.27 a	13.47 a	6954 b	5986
W_4 x F_2	102.1 a	107.4 a	26.25 a	25.58 a			17.86 a	13.13ab	7265 a	6059
LSD 5%	2.584	3.001	0.561	0.720			0.7484	0.457	156.9	NS

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carfentrazone ethyl with 150 kg N + 100 kg P_2O_5 ha^{-1} (W_3 x F_2). Minimum nitrogen and phosphorus uptake by wheat was obtained in the weedy check with no fertilizer application (W_1 x F_0). Nitrogen and phosphorus uptake by wheat was much lower in the weedy check than all of the other weed control practices at each fertilizer level. A similar trend was observed in 2014-15.

The increase in nitrogen and phosphorus uptake by wheat with weed control practices compared, with the weedy check was mainly due to reduced nitrogen and phosphorus uptake by competing with weeds (Tables 1-2). Whereas, in the weedy check, weeds competed more intensely, and depleted a huge amount of nutrients from the soil, causing lower nutrient uptake by wheat. These results are consistent with previous researchers who also stated that weed control practices increased nitrogen uptake by wheat compared with the weedy check (Bazuglov and Gafurov, 2002; Sheibani and Ghadiri, 2011).

Potash uptake by wheat at harvest (kg ha^{-1})

Potash uptake by wheat was significantly affected by the different weed control practices (Table 4). Maximum potash uptake by wheat was recorded with manual weed control (W_4) in both years and was statistically at par with a post-emergence application of isoproturon + carfentrazone ethyl (W_3) in 2013-14, but was significantly greater than all other weed control practices in 2014-15. Minimum potash uptake was recorded in the weedy check (W_1) and this was significant in both years. Different fertilizer levels have also significantly affected potash uptake by wheat in both years. Potash uptake by wheat has significantly increased with each increased fertilizer level and the significantly maximum mean potash uptake by wheat (72.36 kg ha^{-1}) was obtained with 150 kg N + 100 kg P_2O_5 ha^{-1}.

The results of this experiment showed that the nutrient uptake by wheat increased linearly with increase in fertilizer levels and that it can be associated with greater biomass of wheat and availability of nutrients. Although weeds deprive more nutrients at higher fertilizer levels compared with unfertilized plots, wheat is still able to increase its nutrient uptake. The abundance of nutrients at higher fertilizer levels might have reduced the weed crop competition. Our findings agree with those of Blackshaw et al. (2003) and Blackshaw et al. (2004). They reported that nitrogen and phosphorus uptake by wheat increased significantly with increased fertilizer application, however, they did not study the interactive effect of weeds and fertilizer.

Grain yield (kg ha^{-1})

The effect of different weed control practices and fertilizer levels was significant in both years. Maximum grain yield was recorded with manual hoeing against minimum in weedy check. Fertilizer application has significantly increased grain yield of wheat and maximum grain yield was recorded with 150 kg N + 100 kg P_2O_5 ha^{-1}. The interaction between weed control practices and fertilizer levels was significant in 2013-14 and non-significant in 2014-15 (Table 4). In 2013-14, maximum (7,265 kg ha^{-1}) grain yield was obtained with manual hoeing at 150 kg N + 100 kg P_2O_5 ha^{-1} (W_4 x F_2); whereas the minimum (3,865 kg ha^{-1}) was obtained in weedy check with no fertilizer application (W_1 x F_0). At each fertilizer level all weed control practices produced higher grain yield than a weedy check (W_1) and the maximum grain yield was obtained in manual hoeing. Post-emergence application of isoproturon + carfentrazone ethyl (W_3) produced higher grain yield than the pre-emergence application of pendimethalin (W_2) except at 75 kg N + 50 kg P_2O_5 ha^{-1} (F_1) where, both these weed control practices resulted in statistically similar grain yield.

Lower grain yield in weedy check treatment was mainly due to lower spike bearing tillers, the number of grains per spike and 1,000 grain weight. Significantly lower grain yield in weedy check over chemical and non-chemical weed control had also been reported by Arif et al. (2004) as well as by Soltani and Saeedipour (2015), who, however, did not study the interactive effect of fertilizer and weed control practices. More grain yield with higher fertilizer application was probably due to a greater number of grains per spike and 1,000 garin weight, which contributed to higher grain yield. Significantly higher grain yield of wheat due to fertilizer application had also been reported by Yilmaz (2003) and Soltani and Saeedipour (2015) who studied the effect of fertilizer alone. However, in our study, the effect of weed control has also been studied.

Fertilizer use efficiency in wheat (kg kg^{-1})

The interaction between weed control practices and fertilizer levels for fertilizer use efficiency was significant in both the years (Table 4). In 2013-14, maximum fertilizer use efficiency (17.91 kg kg^{-1}) was recorded with pre-emergence application of pendimethalin at 150 kg N + 100 kg P_2O_5 ha^{-1} (W_2 x F_2) and was statistically at par with post-emergence application of isoproturon + carfentrazone ethyl and manual hoeing at 150 kg N + 100 kg P_2O_5 ha^{-1} (W_3 x F_2 and W_4 x F_2) in 2013-14. Whereas, in 2014-15, maximum fertilizer use efficiency was obtained with post-emergence application of isoproturon + carfentrazone ethyl at 150 kg N + 100 kg P_2O_5 ha^{-1} (W_3 x F_2) and was statistically similar to manual hoeing at 150 kg N + 100 kg P_2O_5 ha^{-1} (W_4 x F_2). The minimum fertilizer use efficiency was obtained with a weedy check at 75 kg N + 50 kg P_2O_5 ha^{-1} (W_4 x F_1) in both the years.

Lower fertilizer use efficiency in the weedy check can be attributed to more up take of nutrients by weeds (Tables 1-4). Fertilizer use efficiency increased with increase in fertilizer level in both the years. The increase in fertilizer use efficiency with increased fertilizer level might have been due to higher grain yield as a result of more nutrient absorption.

This present study has come to the conclusion that increased dose of fertilizer has increased nutrient uptake by wheat as well as by weeds. However, increased nutrient losses due to greater uptakes by weeds at higher fertilizer rates can be successfully reduced through suitable weed control practices. Among the various fertilizer doses and weed control practices, higher fertilizer rate (150 kg ha^{-1} N + 100 kg ha^{-1} P_2O_5) and manual weeds control rendered more NPK use efficiency and grain yield, followed by isoproturon + carfentrazone ethyl applied at 750 g a.i. ha^{-1} with a higher dose of fertilizer. Therefore, efficient use of fertilizer can be achieved through effective weeds control practices. Thus, in order to achieve higher grain yield and higher fertilizer use efficiency, weeds should be controlled along with the use of greater fertilizer levels. These findings can aid farmers in improving grain yield and fertilizer use efficiency by minimizing nutrient losses due to weeds.

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