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Effect of Various Weed Control Methods on Yield and Yield Components of Wheat Under Different Cropping Patterns

MUHAMMAD RIAZ[1], M. AZIM MALIK†, TAHIRA ZAFAR MAHMOOD AND MUHAMMAD JAMIL‡
Weed Management Program, and ‡Sugar Crops Research Program, NARC, Islamabad, Pakistan
†Department of Agronomy, UAAR, Rawalpindi, Pakistan
[1]Correspondence author's e-mail: riaznarc@yahoo.com; jamil_narc@yahoo.com

ABSTRACT

In this study, different weed control methods (chemical, mechanical, hand weeding & their integration) under various cropping patterns (wheat-fallow-wheat; wheat-corn-wheat; wheat-legume-wheat) were compared for their efficiency to control various weed species. Among different weed control methods, integrated weeding i.e. chemical weeding (recommended dose of isoproturon) at 2 - 3 leaf stage of weeds with a follow-up hand weeding after 50 days of crop sowing (WC_6) under wheat-mungbean-wheat cropping pattern, gave promising results. This was closely followed by mechanical weeding after 20 days of crop sowing with a follow-up hand weeding after 50 days of crop sowing (WC_5) and/or two hand weedings after 20 and 40 days of crop sowing (WC_2). These weed control methods significantly affected the yield and yield components of wheat under study during both the study years. The economic analysis of these weed control methods also showed better performance of WC_6 (chemical weeding at 2 - 3 leaf stage of weeds + hand weeding at 50 DAS) as compared to rest of the treatments under all cropping patterns.

Key Words: Wheat; Weeds; Integrated weed control; Cropping pattern; Yield components; *Triticum aestivum* L.

INTRODUCTION

Weed infestation is one of the main causes of low wheat yield in Pakistan, which may reduce yield by 25 - 30% (Nayyar *et al*., 1992). Besides quantitative effects on yield, weeds deteriorate the quality of produce through the physical presence of their seeds and debris. Weed density, type of the weeds, their persistence and crop management practices determine the magnitude of yield loss.

The main weeds of wheat in Pakistan include *Phalaris minor* L. (Canary grass), *Avena fatua* L. (Wild oat), *Chenopodium album* L. (Lamb's quarters), *Medicago polymorpha* L. (Wild medic), *Convolvulus arvensis* L. (Fieldbind weed), *Anagallis arvensis* L. (Blue pimpernel), *Fumaria indica* L. (Fumatory), *Melilotus alba* L. (Sweet clover), *Rumex dentatus* L. (Broad leaf dock) and *Senibera didyma* (Swine cress) (Shamsi & Ahmed, 1984). Wheat crop usually suffer from stress created by weeds through competition for water, nutrients, space and sunlight (Anderson, 1983) along with interference caused by releasing toxic substances into the rhizosphere of the crop plants (Rice, 1984). Apart from increasing the production cost, they also intensify the disease and insect pest problem by serving as alternative hosts. The weed problem is getting from bad to worst in wheat sown under irrigated environments, where cropping intensity is rapidly increasing with the result that weed management through traditional methods as Dab (delayed planting) and hand weeding has become impossible.

The farmers control weeds in wheat during land preparation. Khan and Saghir (1987) pointed out that traditional hand weeding is slow, tedious and labour oriented. Labour input is not only getting expensive but is becoming scanty too and at present the cost of hand weeding is about Rs. 5600 ha^{-1}. Very few farmers practice rotation for controlling weeds. Moreover, in the irrigated areas of Pakistan wheat is sown mostly by broadcasting seed in which weeding is difficult (Byerlee *et al*., 1986).

Recently, quite a large number of farmers have started using herbicides. The use of herbicides, however, is too un-economical in addition to resulting in serious ecological and environmental problems such as increase in herbicide resistance in the weeds, ground water contamination and environmental pollution. In fact, none of the weed control methods is best under all conditions. So, there is a need to make a comparative study of different weed management techniques in wheat and to develop an integrated weed management approach, which should be efficient and cost effective and environmentally safe.

This study was planned to integrate different weed control methods in rain-fed wheat crop to identify cost effective weed control methods in wheat based cropping patterns and to study the phytotoxic effect of herbicides on different crops in order to achieve sustainable rain-fed wheat yield.

MATERIALS AND METHODS

The field experiment was conducted under rain-fed conditions for two crop years (2002 - 03 & 2003 - 04) at National Agricultural Research Centre (NARC), Islamabad. The experiments were laid out using two factors, in-split plot design with three replications. The cropping patterns were placed in the main plots and weed control methods in sub-plots. *Avena futua* L. (Wild oat), *Fumaria indica* L. (Fumatory), *Euphorbia helioscopia* L., *Melilotus indica* L.,

Chenopodium album L. (Lamb's quarters), *Medicago polymorpha* L. (Wild medic), and *Convolvulus arvensis* L. (Fieldbind weed) were the main weed species found in wheat field. Six weed control methods included in the study were (i) Weedy check (WC_1): No weed control during rabi and kharif, (ii) Hand weeding at 20 and 40 DAS (WC_2): (complete weed control) during rabi and kharif through hand weeding, (iii) Mechanical weeding at 20 DAS (WC_3), (iv) Chemical weeding (WC_4) at 2 - 3 leaf stage of weeds, (v) Mechanical weeding at 20 days after sowing + hand weeding at 50 DAS (WC_5) and (vi) Chemical weeding at 2 - 3 leaf stage of weeds + hand weeding at 50 DAS (WC_6). The four cropping patterns considered in the study were (i) Wheat-fallow-wheat (CP_1), (ii) Wheat-corn-wheat (CP_2), (iii) Wheat-mungbean-wheat (CP_3) and (iv) Wheat-cowpeas-wheat (CP_4).

Wheat variety Wafaq 2001 was planted in the middle of November in 25 cm apart rows. A local recommended maize variety was planted in the month of July in rows 75 cm apart 20 cm plant to plant distance. Mungbean variety NCM-209 was planted in the second week of July in rows 25 cm apart. Similarly, for cowpeas, a local recommended variety was sown in July. Recommended plant population was maintained for all crops.

All other agronomic operations except those under study were kept normal and uniform for all the treatments. Standard procedures were adopted for recording the data on various growth and yield parameters. Data collected were statistically analyzed by using the Fisher's Analysis of Variance technique and Duncan`s New Multiple Range (DNMR) test at 0.05 P was applied to compare the differences among treatments (Steel & Torrie, 1984).

RESULTS AND DISCUSSION

1. Number of tillers m^{-2}. Different cropping patterns affected significantly the number of tillers during both the years of study. Maximum tillers were recorded under CP_4 followed by CP_2. Rest of the cropping patterns (CP_1 & CP_3) showed significantly lower tillers, which were statistically at par with each other.

Statistically significant differences in number of tillers were observed due to different weed control methods during the study years. Maximum number of tillers (261.89 m^{-2}) was found in case of WC_6 followed by 257.7 m^{-2} in case of WC_5. WC_2 also showed better performance as compared to WC_3 and WC_4 during both years (Table I). The increase in number of tillers as compared to weedy check was possibly due to effective weeding at proper time resulting in less competition of weeds with wheat for growth factors. These results are in line with the previous findings of Ahmad *et al.* (1989), who reported that water shower after spray application of Arelon @ 1.5 kg ha^{-1} proved to be beneficial by producing more productive tillers, which were at par with hand weeding. The increase in number of tillers as compared to weedy check in all the weed control treatments indicated that the possibility of better availability of plant nutrients and favorable environment under weed free conditions resulted by various weed control methods during both years.

2. Plant height. All cropping patterns showed significant results during the study years. CP_2 and CP_4 produced longer plants, while CP_1 showed comparatively poor performance in terms of plant height (Table I).

It is clear from the data that plant height of wheat was also significantly affected by different weed control methods (Table I). WC_6 caused maximum increase in plant height (109.8 cm) followed by WC_5 that resulted in 104.8 cm plant height at maturity. The increase in wheat plant height was possibly due to better weed suppression at proper time resulting in maximum utilization of moisture and nutrients by the crop during both years. It is apparent from the data that mechanical weeding followed by a hand weeding after 50 days of crop sowing (WC_5) resulted in about 12% improvement in plant height and was statistically better than rest of the treatments except WC_6. The efficiency of chemical weeding at 2 - 3 leaf stage of weeds (WC_4) was also significant during both years of study. The taller plants in these treatments were due to better weed control. Plant height of 100.2 cm was obtained with two hand weedings after 20 and 40 days of crop sowing (WC_2), which was also significantly better than that of weedy check (WC_1) and mechanical weeding at 20 DAS (WC_3) as well. Weeding at proper time successfully reduced competition between crop plants and weeds and in turn resulted in healthy crop stand. Similar results have also been reported by Ahmad *et al.* (1984).

3. Spike length. All cropping patterns showed significant results during the study years. The highest spike length of wheat was obtained under CP_4 closely followed by CP_2 during the study years, while CP_1 and CP_3 comparatively did not affect the spike length of wheat (Table I).

Different weed control methods increased the spike length significantly. The results showed that maximum spike length was obtained with WC_6 followed by WC_2 during both years of study (Table I). Other treatments i.e. WC_3, WC_4 and WC_5 also had a significant effect on spike length of wheat crop but their performance was some-what poor than WC_6 and WC_2. The increase in spike length of wheat due to both these treatments (WC_6 & WC_2) was about 62 and 56%, respectively over control (WC_1). A considerable increase in spike length, because of these treatments was probably due to reduced weed competition and availability of adequate amount of plant nutrients and moisture to crop plants. The increase in spike length by weed control methods is well documented by Verma and Chaturvedi (1985), Verma and Kumar (1986), Bhan (1987) and Ahmad *et al.* (1989).

4. Number of spike-lets $spike^{-1}$. A non-significant effect of cropping patterns on spike-lets $spike^{-1}$ of wheat was found during both study years (Table I). However, the highest number of spike-lets per spike in case of CP_2 may be attributed complete eradication of weeds. Among all the

Table I. Effect of different cropping patterns and weed control methods on yield and yield components of wheat

Treatments	No. of tillers (m^{-2})	Plant height (cm)	Spike length (cm)	No. of spike-lets $spike^{-1}$	No. of grains $spike^{-1}$	1000-grain wt. (g)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Total Biol. yield ($t\ ha^{-1}$)	Harvest index (%)
A. Years										
Y_1	246.03b*	101.00b*	10.44b*	23.47b*	48.39b*	46.40b*	2.683b*	5.682b*	8.550b*	31.02b*
Y_2	249.67a	101.97a	10.97a	24.17a	49.54a	47.76a	2.850a	5.717a	8.575a	33.08a
B. Cropping patterns										
CP_1	247.19c*	100.53c*	10.39c*	23.58NS	48.08b*	46.19b*	2.687d*	5.665NS	8.526b*	31.28c*
CP_2	248.03b	102.08a	10.81ab	24.06	49.19a	47.03ab	2.776c	5.709	8.572a	32.10b
CP_3	247.03c	101.28b	10.67bc	23.86	48.89ab	48.00a	2.808a	5.716	8.579a	32.48a
CP_4	249.14a	102.06a	10.97a	23.78	49.69a	47.11ab	2.796b	5.711	8.574a	32.36a
C. Weed Control Methods										
WC_1	233.04f*	98.12e*	7.88e*	17.08e*	40.54f*	38.63c*	2.078f*	5.198d*	7.487f*	27.76f*
WC_2	253.71c	100.21d	12.29b	26.42b	48.58c	51.96a	3.392b	6.397a	9.864b	34.39b
WC_3	237.96e	94.21f	10.79c	21.75d	45.92e	45.67b	2.300e	5.228d	7.594e	30.30e
WC_4	242.87d	101.83c	10.17d	23.58c	47.50d	46.79b	2.524d	5.284c	7.883d	32.02d
WC_5	257.71b	104.79b	10.37cd	26.25b	52.04b	46.13b	2.836c	5.725b	8.636c	32.87c
WC_6	261.79a	109.75a	12.75a	27.83a	59.21a	53.33a	3.469a	6.369a	9.914a	34.99a

Y_1=1st year, Y_2=2nd year, CP_1= were wheat-fallow-wheat, CP_2= wheat-corn-wheat, CP_3= wheat-mungbean-wheat, CP_4= wheat-cowpeas-wheat, WC_1= Weedy Check, WC_2= Hand Weeding at 20 and 40 DAS, WC_3= Mechanical Weeding at 20 DAS, WC_4= Chemical Weeding at 2-3 leaf stage of weeds, WC_5= Mechanical Weeding at 20 DAS + Hand Weeding at 50 DAS, WC_6= Chemical Weeding at 2-3 leaf stage of weeds + Hand Weeding at 50 DAS; * Means not sharing a letter in common within treatments differ significantly at 5% probability level; NS = Non significant

weed control methods, WC_3 showed comparatively poor performance but on an average, it was about 27% better than that of WC_1 (Table I). On the other hand, when a follow-up hand weeding after 50 days of crop sowing (WC_5) was done, a further increase of about 27% in number of spike-lets per spike was observed due to effective weeding at proper time. WC_6 produced maximum number of spike-lets $spike^{-1}$ followed by WC_2 and WC_5. The better performance of WC_6, WC_2 and WC_5 as compared to rest of the treatments could be due to effective weed control, which ultimately facilitated healthy crop stand and resulted in the highest number of spike-lets $spike^{-1}$ during both years.

5. Number of grains $spike^{-1}$. The data revealed that better number of grains $spike^{-1}$ was produced under CP_2 and CP_4 closely followed by CP_3 during both study years. The number of grains $spike^{-1}$ was significantly affected by various weed control methods during both years (Table I). Maximum number of wheat grains $spike^{-1}$ (59.21) was observed with WC_6 followed by WC_5 having 52.0 grains $spike^{-1}$ (Table I). Two hand weedings after 20 and 40 days of crop sowing (WC_2) also produced promising results but its efficiency was less than that of WC_6 and WC_5. Maximum grain production with efficient weeding treatments may be attributed to supportive action of weed control techniques described by Singh and Sharma (1984), Pandey and Singh (1985), Parihar *et al.* (1986), Rajput *et al.* (1988), Tanweer *et al.* (1990) and Tomar *et al.* (2003).

6. 1000-Grain weight. Maximum 1000-grain weight of wheat was produced with CP_3 closely followed by CP_4 and CP_2. The CP_1 produced statistically less 1000-grain weight than rest of the cropping patterns (Table I). The data also revealed that more number of grains $spike^{-1}$ was produced under CP_2 and CP_4 closely followed by CP_3 during both study years (Table I). As far as the effect of weed control methods on 1000-grain weight is concerned, different weed control treatments significantly influenced the 1000-grain weight of wheat. Maximum 1000-grain weight was obtained with WC_6 and WC_2 during both the years. Rest of the treatments (WC_3, WC_4 & WC_5) produced similar and comparatively less 1000-grain weight but were statistically better than that of WC_1. On an average, these treatments (WC_3, WC_4 & WC_5) showed about 27% increase in 1000-grain weight as compared to WC_1. The better performance in case of WC_6 and WC_2 (about 48 & 43% increase over WC1, respectively) has also been discussed previously. The weeding at proper time with an adequate source could provide healthy environment for the crops and ultimately better yields. This is quite possible that weed free good crop stand produced robust grains and ultimately resulted in more 1000-grain weight. Similar results have also been reported by Cheema *et al.* (1997), Singh and Prasad (1998), Narkhede *et al.* (2000), Tomar *et al.* (2003) and Kumari and Prasad (2003). While the results reported by Margin *et al.* (1984) showed no effect on grain weight of wheat by eliminating weed competition.

7. Grain yield of wheat. A significant effect of cropping patterns on grain-yield of wheat crop was also found during the years of study. The maximum grain yield was recorded with CP_3 than rest of the cropping patterns (Table I). This might be due to the inclusion of legumes that enhanced soil fertility and resulted in maximum grain yield of wheat. The data regarding grain yield of wheat as affected by different weed control methods also revealed that all the weed control treatments increased wheat grain yield during both years of study (Table I). Maximum grain yield (3.5 tonnes ha^{-1}) was obtained with WC_6 followed by (3.4 tonnes ha^{-1}) WC_2 during the study period. WC_6 and WC_2 produced approximately 67 and 63%, respectively more grain yield of wheat over weedy check. Among all the weed control methods, WC_3 showed poor performance, but was slightly better than WC_1. A follow-up hand weeding after 50 days of crop sowing (WC_5) interestingly improved grain yield of wheat by about 25%. This indicates that re-emergence of weeds later on occurred during crop growth period and caused a considerable reduction in grain yield. Similar findings have also been narrated by Cheema (1988), Tanweer *et al.* (1990) and Pandey and Mishra (2002).

8. Straw yield of wheat. Various cropping patterns showed

non-significant results during the study years (Table I). However, maximum straw yield was found in case of CP_3, while all other cropping patterns (CP_1, CP_2 & CP_4) produced comparatively lower straw yield. Different weed control methods significantly affected straw yield of wheat during the study period. WC_6 and WC_2 out yielded in terms of straw yield as compared to rest of the treatments (Table I). These treatments produced about 22 and 23%, respectively more straw yield as compared to weedy check (WC_1). WC_5 also showed statistically significant increase in straw yield of wheat during the study years. The poor performance of WC_3 and WC_4 was probably due to inadequate weeding at initial stage of crop and re-emergence of weeds during crop growth period, resulting in less crop biomass. Decrease in crop biomass as a result of weeds has also been reported by Tiwari *et al.* (1984). The increase in wheat biomass (straw yield) under various treatments may be attributed to suppression of weed density and growth that also favored increase in number of tillers m^{-2} and plant height. Significantly higher straw yield in weed control treatments compared to weedy check has also reported by Sarwar (1994), Pandey and Mishra (2002) and Roslon and Fozelfors (2003).

9. Biological yield. Maximum biological yield was produced by CP_2, CP_3 and CP_4 during the study years, while CP_1 gave less total biological yield. The effect of different weed control methods on total biological yield of wheat was statistically significant during both the years of study (Table I). WC_6 out yielded significantly followed by WC_2. These treatments (WC_6 & WC_2) increased approximately 32 and 31%, respectively biological yield of wheat over control (WC_1). Among all weed control methods, WC_3 showed poor performance than rest of the treatments, but was statistically better than that of WC_1. However, its efficiency was further increased about 14% with a follow up hand weeding after 50 days of crop sowing. Significant increase in total biological yield of crops due to weed control methods has also been reported by Tiwari *et al.* (1984), Pandey and Mishra (2002) and Roslon and Fogelfors (2003).

10. Harvest index. The effect of different cropping patterns on the harvest index of wheat was found statistically significant during both years of study. The maximum harvest index (32.5 & 32.4%) of wheat was calculated for CP_3 and CP_4, respectively. It is clear from the data that the harvest index of wheat crop as affected by different weed control methods showed significant differences during the study years (Table I). Among various weed control treatments, higher value of harvest index (35%) was recorded for plots, where chemical weeding at 2 - 3 leaf stage of weeds with a follow up hand weeding after 50 days of crop sowing (WC_6) were applied. Twice hand weeding after 20 and 40 days of crop sowing (WC_2) also resulted in high harvest index value of 34.4% during the study years. The other treatments showed comparatively lower value of harvest index being minimum with WC_3 but were statistically higher than WC_1. The significant increase in harvest index may be attributed to suppression of weed growth resulting in more availability of plant nutrients to wheat crop, which favored utilization of photo synthates for better grain yield formation. Similar conclusions have also been drawn by Salisbury and Ross (1978) and Sarpe *et al.* (1986). The lower harvest index value in case of WC_3 might be due to ineffective weed control. The lower harvest index value at higher weed density has been discussed by Sarwar (1994).

Economic analysis. The economic analysis (Table II) revealed that WC_6 proved to be the best weed control method under all cropping patterns followed by WC_2 during both years of study except CP_4. Although WC_6 gave higher return (Rs. = 25120.96) than rest of the weed control treatments under CP_1, but the net benefit was less than other cropping patterns (CP_2, CP_3 & CP_4). Maximum net benefit of Rs. 77837.80 was obtained with treatment WC_6 under CP_2 in both the study years. It decreased gradually under CP_3, CP_4 and CP_1 cropping patterns with rest of the treatments. Among all weed control methods,

Table II. Net benefit of various Cropping Patterns under different weed control methods

Treatments	CP_1	CP_2	CP_3	CP_4
WC_1 (Weedy Check)	12201.25	50304.25	45725.78	40147.58
WC_2 (Hand Weeding at 20 and 40 DAS)	23697.25	72247.77	66641.77	60972.75
WC_3 (Mechanical Weeding at 20 DAS)	13961.50	61398.25	61021.95	48588.75
WC_4 (Chemical Weeding at 2-3 leaf stage of weeds)	15388.30	64172.82	64313.99	52737.49
WC_5 (Mechanical Weeding at 20 DAS + Hand Weeding at 50 DAS)	17725.00	68549.48	66595.25	61970.27
WC_6 (Chemical Weeding at 2-3 leaf stage of weeds + Hand Weeding at 50 DAS)	25120.96	77837.80	75112.74	73206.02

CP_1= Wheat - Fallow – Wheat, CP_2= Wheat - Corn – Wheat, CP_3= Wheat - Mungbean – Wheat, CP_4= Wheat - Cowpeas – Wheat

Table III. Cost benefit ratio of various Cropping Patterns under different weed control methods

Treatments	CP_1	CP_2	CP_3	CP_4
WC_1 (Weedy Check)	1.82	2.81	2.65	2.41
WC_2 (Hand Weeding at 20 and 40 DAS)	2.13	2.82	2.68	2.51
WC_3 (Mechanical Weeding at 20 DAS)	1.85	2.99	2.99	2.54
WC_4 (Chemical Weeding at 2-3 leaf stage of weeds)	1.88	2.95	2.95	2.52
WC_5 (Mechanical Weeding at 20 DAS + Hand Weeding at 50 DAS)	1.91	2.86	2.81	2.65
WC_6 (Chemical Weeding at 2-3 leaf stage of weeds + Hand Weeding at 50 DAS)	2.23	3.00	2.93	2.81

CP_1= Wheat - Fallow – Wheat, CP_2= Wheat - Corn – Wheat, CP_3= Wheat - Mungbean – Wheat, CP_4= Wheat - Cowpeas - Wheat

WC_3 showed the lowest net benefit but higher than weedy check (WC_1), which was Rs. 13961.50, Rs. 61398.25, Rs. 61021.95 and Rs. 48588.75 under CP_1, CP_2, CP_3 and CP_4, respectively. WC_2 under all cropping patterns proved to be the next efficient weed control method after WC_6 under all cropping patterns except CP_4. This method of weed control (WC_2) gave maximum return (Rs. 72247.77) but less than WC_6 under cropping pattern CP_2 during the study period 2002 - 04.

The cost benefit ratio of various weed control methods under different cropping patterns (Table III) revealed that WC_6 proved to be better than rest of the weed control methods except under all cropping patterns during both of the study years. Cost benefit ratios for different combinations under study, WC_6 x CP_1, WC_6 x CP_2 and WC_6 x CP_4 gave the highest values of 2.23, 3.00 and 2.81, respectively during both the years of study. However, WC_3 gave higher benefit ratio (2.99) under CP_3. Higher benefit ratio due to integrated weed control method might be attributed to better suppression of weeds that have resulted in more yields under various cropping patterns.

CONCLUSION

There was a significant increase (about 58% & 54%) in grain yield of wheat due to chemical weeding at 2 - 3 leaf stage of weeds + hand weeding at 50 DAS (WC_6) and two hand weedings after 20 and 40 DAS (WC_2), respectively. Similarly, both these treatments (WC_6 & WC_2) out yielded other treatments in terms of biomass production during both of the study years. As far as cropping patterns are concerned, CP_3 and CP_4 proved significantly better. The inclusion of leguminous crop increases the overall soil fertility and helped in conservation of soil moisture, which gave better yield.

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