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Yield and Yield Components of Maize as Affected by Various Weed Control Methods Under Rain-fed Conditions of Pakistan

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ABSTRACT

A field study was conducted at National Agricultural Research Centre (NARC), Islamabad, during two crop years (2003 - 04) to determine the effect of different weed control methods on the yield and yield components of maize (*Zea mays* L.). In this study, different weed control methods (chemical, mechanical, hand weeding & their integration) were compared for their efficiency to control various weed species under rain-fed conditions of Pakistan. Among different weed control methods, chemical weeding at 2 - 3 leaf stage of weeds + hand weeding at 50 DAS gave promising results (1.7 g m^{-2}). 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 and/or two hand weedings after 20 and 40 days of crop sowing. These weed control methods significantly controlled weeds and enhanced yield (42%) and yield components of wheat during both the study years. The economic analysis of these weed control methods also showed better performance of chemical weeding at 2 - 3 leaf stage of weeds + hand weeding at 50 DAS as compared to rest of the treatments.

Key Words: Maize; Weeds; Integrated weed control; Yield components

INTRODUCTION

In Pakistan, maize ranks third after wheat and rice among the cereals. In rain-fed area, it ranks second to wheat with an area of 7000 ha and an average yield of 0.7 tonnes ha^{-1}. National yield of progressive farmers and at the experimental stations is comparatively higher than the average yield of rain-fed areas. There are many socio-economic, physical and biological factors that limit the productivity of maize crop in the area. One of the major problems in the area is posed by the weeds, which have shown to reduce the yields from 25 - 50%. In rain-fed areas inter-culture of maize fields is done for controlling weeds, which is costly and time and labour consuming. Integrated weed management is the need of the day, because of its sustainability and higher productivity. Different weed control methods were compared to investigate their efficiency for enhancing maize yield during the growing season of. The yield and yield components of maize crop are being discussed under this section:

Weeds are of negative values, which lower the input efficiency. 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 maize in Pakistan include *Trianthema monogyna*, *Cyperus rotundus*, *Sorghum halepense*, *Digera arvensis*, *Echinochloa colona* and *Cynodon dactylon*. Maize crop usually suffers from stress created by weeds through competition for water, nutrients, space and sunlight (Anderson, 1983). Apart from increasing the production cost, they also intensify the disease and insect pest problem by serving as alternative hosts. In barani areas of Pakistan maize crop forms an important portion of cropping system. The yield of the crop is very low, which could be increased with proper management of production factors. 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 maize and to develop an integrated weed management approach, which should be efficient and cost effective and environmentally safe. Keeping these facts in view, a comprehensive 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 maize 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 experiment, were laid out in RCBD with 3 replications. *Trianthema monogyna*, *Cyperus rotundus*, *Sorghum halepense*, *Digera arvensis*, *Echinochloa colona* and *Cynodon dactylon* were the main weed species found in maize field. Six weed control methods were included in the study. These were weedy check (WC_1): No weed control during rabi and kharif, hand weeding at 20 and 40 DAS (WC_2): (complete weed control) during rabi and kharif through hand weeding, mechanical weeding at 20 DAS

(WC_3), chemical weeding (WC_4) at 2 - 3 leaf stage of weeds, mechanical weeding at 20 days after sowing + hand weeding at 50 DAS (WC_5) and chemical weeding at 2 - 3 leaf stage of weeds + hand weeding at 50 DAS (WC_6). A local recommended maize variety (Gohar) was planted in the month of July in rows 75 cm apart 20 cm plant to plant distance. 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

Weed Density and Dry Biomass

Weed density (m^{-2}). A significant difference between years regarding the density of *Trianthema monogyna, Cyperus rotundus, Sorghum halepense and Digera arvensis*, was recorded being minimum during the second year (Table I). This might be due to minimum weed seed bank and complete eradication of weeds during this year. The effect of years on density of *Echinochloa colona* and *Cynodon dactylon* was found to be non-significant (Table I).

The data regarding the effect of different weed control methods on *Trianthema monogyna, Cyperus rotundus, Sorghum halepense, Digera arvensis, Echinochloa colona* and *Cynodon dactylon* density at maturity showed that maximum reduction in density of the weeds was observed with the treatment WC_6 followed by WC_2 and WC_5. Comparatively less reduction in weed density was observed with WC_3 and WC_4. Many other research workers have also been reported that weed seeds remain under dry conditions and germinate upon availability of moisture (Unger *et al.*, 1999; Tomar *et al.*, 2003).

Weed dry biomass (g m^{-2}). The effect of years on density of *Trianthema monogyna, Cyperus rotundus, Sorghum halepense, Digera arvensis, Echinochloa colona* and *Cynodon dactylon*, was found to be non-significant (Table II). Similar trend was found in case of weed dry biomass as observed in weed density. The dry biomass of *Trianthema monogyna, Cyperus rotundus, Sorghum halepense, Digera arvensis, Echinochloa colona* and *Cynodon dactylon* dry biomass at maturity was maximum reduced with the treatment WC_6 followed by WC_2 and WC_5. Comparatively less reduction in weed density was observed with WC_3 and WC_4 (Table II).

Yield Component and Yield of Maize

Plant height (cm). The data regarding plant height of maize as affected by study years were found statistically non-significant (Table III). On the other hand, all weed control methods showed significant effect on plant height of maize. The maximum plant height was observed with WC_6 and WC_5. Ahmad *et al.* (1988), Behera *et al.* (1998) and Williams *et al.* (1998) have reported similar results obtained from various weed control techniques.

Number of ears (plant^{-1}). The year effect on number of ears plant^{-1} was not significantly different during the study period (Table II). It is evident from the data that number of ears plant^{-1} of maize is affected significantly by different weed control methods during both years being maximum with WC_6 followed by WC_2. The rest of the treatments were equally affective during both years of study.

1000-Grain weight (g) of maize. The data regarding 1000-grain weight in Table III reveals that there was no significant difference between study years. But it was significantly affected by different weed control treatments being maximum with WC_6 closely followed by WC_5 and WC_2. This increase in 1000-grain weight was possibly due to effective weed control, which resulted in healthy crop stand and ultimately higher grain weight. These results get support from the previous findings of Ahmad *et al.* (1988) and Khan *et al.* (1991). Kandasamy and Chandrasekhar (1998) reported that the traditional (non-chemical) method of weed control effectively minimized weed competition and maximized maize yield.

Grain yield (tonnes ha^{-1}). The data (Table III) reveal that, between study years, a significant difference in grain yields of maize was observed being maximum in second year. This might be due to minimum weed seed bank and eradication of weeds providing healthy environment for crop plant growth during this year. A significant affect of different weed control methods was observed on grain yield of maize during both years of study. Among various weed control methods, WC_6 showed promising results during both years of study. A 34% increase in grain yield of maize was observed due to effective weeding by this treatment (WC_6) followed by about 33% increase in grain yield with WC_5 and about 32% increase with WC_2 as compared to WC_1. Jehangeri *et al.* (1984) reported that application of selective herbicides provided 65 to 90% weed control and 100 to 150% more grain yield of maize than un-weeded control. They further demonstrated that chemical method of weed control in maize was more effective than the mechanical one.

Stalk yield (tonnes ha^{-1}). It is clear from the Table III that statistically non-significant difference was observed in stalk yield of maize crop between study years. On the other hand all the weed control treatments showed statistically similar results with the exception of WC_3. The lower yield in case of WC_3 was due to inadequate weeding as discussed by Floot (1996) and Pizzi *et al.* (1996). The treatment WC_6 out yielded among all the weed control treatments that were approximately 33% higher as compared to control (WC_1) treatment. The treatments WC_5 and WC_2 were next to WC_6. Both of these treatments (WC_5 & WC_2) caused increase in stalk yield of maize over control (WC_1) treatment. These results are in line of those reported by Ahmad *et al.* (1988), Kandasamy and Chandrasekhar (1998) and Singh *et al.* (2002).

Table I. Effect of different cropping patterns and weed control methods on density of different weeds of maize

Treatments	Trianthema monogyna	Cyperus rotundus	Sorghum halepense	Digera arvensis	Echinochloa colona	Cynoden dactylon
			a. Years			
Y_1	15.96a*	14.50a*	31.34a*	14.06a*	29.06NS	37.47NS
Y_2	15.00b	14.31b	30.44b	13.40b	29.76	37.56
			b. Weed Control Methods			
WC_1	36.67 a*	135.33 a*	72.67 a*	42.67 a*	181.33 a*	72.50 a*
WC_2	3.83 c	12.50 c	7.33 cd	4.50 c	15.83 cd	15.67 bc
WC_3	8.83 b	29.17 b	20.17 b	9.83 b	41.50 b	14.33 c
WC_4	7.67 b	10.17 cd	16.50 c	6.17 bc	36.17 bc	20.33 b
WC_5	7.83 b	12.00 c	6.17 cd	4.17 c	14.17 cd	11.00 d
WC_6	3.67 c	7.83 d	4.17 e	3.67 cd	8.17 d	12.17 cd

Y_1=1st year, Y_2=2nd year, 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

Table II. Effect of different cropping patterns and weed control methods on dry biomass of different weeds of maize

Treatments	Trianthema monogyna	Cyperus rotundus	Sorghum halepense	Digera arvensis	Echinochloa colona	Cynoden dactylon
			a. Years			
Y_1	6.78NS	5.13NS	26.42NS	11.31NS	17.02NS	28.99NS
Y_2	6.68	5.06	25.71	10.69	16.88	27.47
			b. Weed Control Methods			
WC_1	14.22 a*	48.94 a*	62.69 a*	36.32 a a	106.36 a*	41.60 a*
WC_2	1.64 d	3.32 d	5.79 d	4.00 d	8.33 d	12.83 bc
WC_3	4.33 b	11.07 b	19.83 b	9.16 b	28.66 b	13.45 b
WC_4	3.10 c	4.05 c	12.47 c	7.31 c	19.35 c	13.20 b
WC_5	3.35 c	3.74 d	6.31 d	3.28 d	7.10 d	8.00 c
WC_6	1.73 d	2.59 e	4.00 e	3.50 d	4.15 e	6.77 d

Y_1=1st year, Y_2=2nd year, 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

Table III. Effect of different cropping patterns and weed control methods on yield and yield components of maize

Treatments	Plant height (cm)	No. of Ears (plant-1)	1000-grain wt. (g)	Grain yield (tonnes ha-1)	Stalk yield (tonnes ha-1)	Harvest Index (%)
				a. Years		
Y_1	186.44NS	1.13NS	268.56NS	4.549 b*	11.013NS	38.10b*
Y_2	186.50	1.18	276.44	4.754 a	12.128	43.15a
				b. Weed Control Methods		
WC_1	172.67c*	0.80 d*	258.00d*	3.64 e*	10.204d*	37.65b*
WC_2	188.83ab	1.32 b	275.83ab	4.880 b (34.1)[2]	12.141ab	40.57a
WC_3	185.00b	1.00 c	270.67c	4.515 d (24.0)	10.910c	41.80a
WC_4	188.00ab	1.00 c	273.17bc	4.646 c (27.6)	11.603b	40.68a
WC_5	191.17a	1.00 c	277.00ab	4.942 b (35.8)	12.007ab	41.64a
WC_6	193.17a	1.81 a	280.33a	5.163 a (41.8)	12.5637a	41.43a

Y_1=1st year, Y_2=2nd year, 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

[2]% increase compared with control

Harvest index (%) of maize. The data in Table III indicate that a significant difference in % harvest index of maize was for both study years being maximum during the second year. This was probably due to adequate crop yield during this year. The % values for harvest index of maize crop as affected by different weed control methods showed significant differences among the treatments during both study years. The increase in percentage of harvest index as compared to WC_1 may be attributed to adequate suppression of weed growth due to some residual effect as well and more availability of plant nutrients to maize crop, which favoured better utilization of photo-assimilates for grain yield formation. Similar results have also been discussed by Salisbury and Ross (1978), and Ahmad *et al.* (1988).

Table IV. Economic analysis of various weed control treatments in maize

	T_1	T_2	T_3	T_4	T_5	T_6	Remarks
Total Corn grain yield for two Year	3640.00	4880.00	4515.00	4646.00	4942.00	5163.00	kg ha^{-1}
10% less (than actual yield)	364.0	488.0	451.5	464.6	494.2	516.3	kg ha^{-1} (to bring it at farmer level)
Adjusted yield	3276.0	4392.0	4063.5	4181.4	4447.8	4646.7	kg ha^{-1}
Gross income (ha^{-1})	24570.0	32940.0	30476.3	31360.5	33358.5	34850.3	Corn grain Price @ 7.5/kg
Hand Weeding	0.0	3000.0	0.0	0.0	1500.0	1500.0	Rs.100/man (one man /day/ha).
Mechanical weeding	0.0	0.0	750.0	0.0	750.0	0.0	Rs. 750 ha^{-1}
Cost of herbicide	0.0	0.0	0.0	1140.0	0.0	1140.0	Isoproturon @ Rs. 1150 ha^{-1}+ Primextra Rs.1140 ha^{-1}
Spray application cost	0.0	0.0	0.0	100.0	0.0	100.0	Rs.100 man^{-1} (one man /day/ha)
Spray rent	0.0	0.0	0.0	50.0	0.0	50.0	Rs.50 $spray^{-1}$
Cost that vary	0.0	3000.0	750.0	1290.0	2250.0	2790.0	Rs. ha^{-1}
Net benefit	24570.0	29940.0	29726.3	30070.5	31108.5	32060.3	Rs. ha^{-1}

T_1= Weedy Check, T_2= Hand Weeding at 20 and 40 DAS, T_3= Mechanical Weeding at 20 DAS, T_4= Chemical Weeding at 2-3 leaf stage of weeds, T_5= Mechanical Weeding at 20 DAS + Hand Weeding at 50 DAS, T_6= Chemical Weeding at 2-3 leaf stage of weeds + Hand Weeding at 50 DAS

Table V. Marginal rates for various weed control treatments in maize

Treatments	Total cost that vary[1] (Rs. ha^{-1})	Net benefits[2] (Rs. ha^{-1})	Marginal rate of return[3] (%)
WC_1 (Weedy Check)	-	24570.0	-
WC_3 (Mechanical Weeding at 20 DAS)	750.0	29726.3	687.5
WC_4 (Chemical Weeding at 2-3 leaf stage of weeds)	1290.0	30070.5	63.75
WC_5 (Mechanical Weeding at 20 DAS + Hand Weeding at 50 DAS)	2250.0	31108.5	108.125
WC_6 (Chemical Weeding at 2-3 leaf stage of weeds + Hand Weeding at 50 DAS)	2790.0	32060.3	432.22
WC_2 (Hand Weeding at 20 and 40 DAS)	3000.0	29940.0	D[4]

[1]The sum of all the costs that vary for a particular treatment; [2]The difference between total costs that vary and the gross benefit for each treatment, [3]The ratio of marginal net benefits and marginal costs expressed as percentage; [4]Dominated treatment, the treatment which have higher costs but lower net benefits

Economic analysis. All the treatments gave higher net benefit as compared to control (Table IV). The treatments T_6 (Chemical Weeding at 2 - 3 leaf stage of weeds + Hand Weeding at 50 DAS) resulted in higher net benefit (Rs. 32060 ha^{-1}). The treatment T_3 (Mechanical Weeding at 20 DAS) had less net benefits (Rs. 29726 ha^{-1}). But in case of marginal analysis (Table V) Mechanical Weeding at 20 DAS (T_3) was found better than all the treatments with maximum marginal rate of return (688%). The treatment T_2 (Hand Weeding at 20 & 40 DAS) was dominated due to less net benefit and higher cost that varied, so it was un-economical treatment at the prevailing crop and herbicide prices. On the basis of this study it is suggested that Chemical Weeding at 2 - 3 leaf stage of weeds + Hand Weeding at 50 DAS or Mechanical Weeding at 20 DAS may be used for controlling weeds in wheat with fairly good economic returns.

CONCLUSION

Maximum reduction in density and biomass of the weeds was observed by chemical Weeding at 2 - 3 leaf stage of weeds + Hand Weeding at 50 DAS (WC_6). There was a significant increase (42%) in grain yield of maize due to chemical weeding at 2 - 3 leaf stage of weeds + hand weeding at 50 DAS (WC_6). Similarly, this treatment (WC_6) out yielded other treatments in terms of number of ears, 1000 grain weight, stalk yield and net benefits.

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