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EVALUATION OF INTEGRATED WEED MANAGEMENT PRACTICES FOR MAIZE

Waheed Ullah[1], Muhammad Azim Khan[1], Shahnaz Arifullah[2] and Muhammad Sadiq[3]

ABSTRACT

An experiment was conducted at Agricultural Research Farm, NWFP Agricultural University Peshawar during summer 2006 to evaluate integrated weed management for maize. Randomized complete block design, having three replications was used in the experiment. The treatments included 1) pendimethaline (Stomp 330 E + high population (90,000 plants ha^{-1}), 2) pendimethaline + medium population (60,000 plants ha^{-1}), 3) Stomp 330E + low population (30,000 plants ha^{-1}), 4) pendimethaline + weeding 4 weeks after sowing (WAS) + high population, 5) pendimethaline + weeding 6 weeks after sowing (WAS) + medium population, 6) pendimethaline + weeding 8 weeks after sowing (WAS) + low population, 7) weeding 4 weeks after sowing (WAS) + high population, 8) weeding 6 weeks after sowing (WAS) + medium population, 9) weeding 8 weeks after sowing (WAS) + low population, 10) weedy check + high population, 11) weedy check + medium population and 12) weedy check + low population. Statistical analysis of the data showed that weed density as well as yield related traits of maize were significantly affected by different treatments. In general weed control methods suppressed the weeds and increased the yield and yield related traits. However, pendimethaline was most effective in combination with hand weeding. CBR indicated that application of pendimethaline and sowing at the rate of 60,000 plants ha^{-1} is the best option for the farmers.

Keywords: *Zea mays*, weeds, integrated weed management, herbicides, hand weeding.

[1]Department of Weed Science, NWFP Agricultural University Peshawar, Pakistan, E-mail: ahmadzaipk@yahoo.com
[2]Institute of Development Studies, NWFP Agricultural University, Peshawar.
[3] Department of Agronomy Gomal University, Dera Ismail Khan.

INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop of Pakistan and in NWFP in particular. It is grown for fodder as well as for grain purpose in NWFP. The grains of maize are used in a variety of ways by the human beings. Recently, with the release of improved cultivars and hybrids, the grain yield has been increased but still the maize crop faces many problems. Farmers usually give prime importance to few cultural practices and neglect other factors like seed rate and weed control. As the maize is usually grown during the hot summer months of May, June and August, when manual method of weed control is difficult to imply therefore, other methods of weed control are more feasible, less laborious, cost effective and economical. Several weed species that are strong competitors, compete with the maize crop and thus the yield is decreased. Weed management strategies attempt to limit the deleterious effects of weeds growing with crop plants. These effects could be quite variable, but the most common is competition for available resources. The quantities of growth factors used by weeds are thus unavailable to the crop. On the other hand, the perennial weeds like *Cyperus rotundus* and *Cynodon dactylon* which are among the worst weeds of the world, infest the maize crop and thus increase the cost of production, as hand weeding is not effective against these weeds. Presence of weeds in maize crop decreases the yield drastically. Malik *et al.* (2006) reported that herbicides proved effective in controlling weeds and produced relatively more weight of cobs, number of grains cob^{-1}, 1000-grain weight, biological yield and grain yield. Similarly plant population and row spacing also affect the weed population. Harvey *et al*. (1997) reported that it is logical to expect that weed management should improve if the row spacing of corn is narrow. These results supports the results of many researchers that plant population per unit area and herbicide use in corn increase the maize yield. In a similar study, Khan *et al.* (2002) reported that chemical weed control as well as hand weeding significantly increased the grain yield of maize. As there are limitations of every weed control method therefore integrated weed management is a good option for sustainable agriculture. It involves the combination of all the possible methods to suppress the weeds below economic threshold level. Although some methods are effective against weeds but they prove uneconomical for the farmers or pose environmental hazards.

Keeping in view the importance of weeds and the yield losses of maize, the present study was initiated with the following objectives:

1. To decipher the effect of weed control methods on weeds and yield related traits of maize.
2. To evaluate the economics of integrated weed management in maize.

MATERIALS AND METHODS

A Field experiment was conducted at Agricultural Research Farm, NWFP Agricultural University, Peshawar, Pakistan during summer 2006. The experimental site had mean soil pH of 7.47 with 22.8, 55.7 and 21.5% clay, silt and sand, respectively. The experiment was laid out in Randomized Complete Block (RCB) design with three replications. Maize variety 'Azam' was used in the study as this is the widely used variety used in the area. Field was ploughed thrice to make a fine seed bed followed by planking. Weather (temperature, rainfall, humidity and soil temperature) data were recorded during the crop season (Fig-1). Experimental field was irrigated as and when needed. The size of each treatment was $3x5m^2$. There were 12 treatments in the experiment with row to row distance of 75 cm, each treatment having four rows. There were three maize populations viz., high (90,000 ha^{-1}), medium (60,000 plants ha^{-1}) and low (30,000 plants ha^{-1}) in combination with different weed control treatments. The seed rate was used higher than the required and then thinning was done after complete germination to maintain the required plant population. Nitrogen was applied at the rate of 120 kg ha^{-1} in the form of urea and 60 kg of P_2O_5 was applied in the form of SSP.

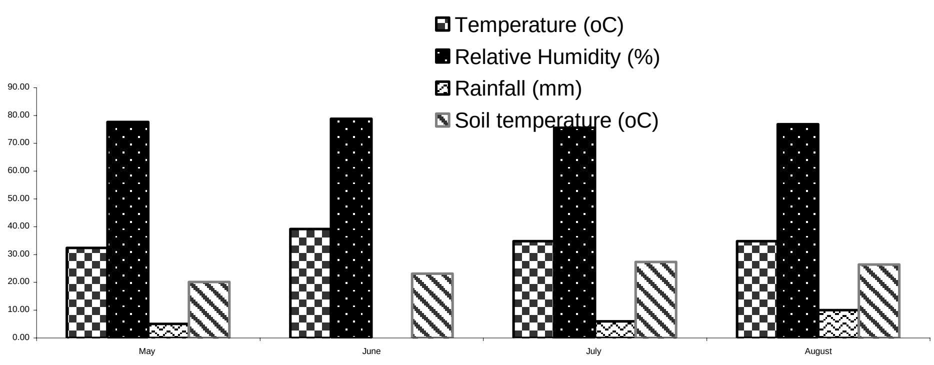

Fig-1. Mean monthly temperature, rainfall, relative humidity and soil temperature data from May to August, 2006

The experiment comprised of the following treatments.

1. Pendimethaline 330E + high population (90,000 plants ha^{-1})
2. Pendimethaline 330E + medium population (60,000 plants ha^{-1})
3. Pendimethaline 330 E + low population (30,000 plants ha^{-1})
4. Pendimethaline 330E + weeding 4 weeks after sowing + high population
5. Pendimethaline 330E + weeding 6 weeks after sowing + medium population
6. Pendimethaline 330E + weeding 8 weeks after sowing + low population
7. Weeding 4 weeks after sowing (WAS) + high population
8. Weeding 6 weeks after sowing (WAS) + medium population
9. Weeding 8 weeks after sowing (WAS) + low population
10. Weedy check + high population
11. Weedy check + medium population
12. Weedy check + low population

During the course of experiment, the data were recorded on weed density m^{-2} 75 days after sowing (DAS), dry biomass of weeds m^{-2} 75 days after sowing (DAS), leaf area (cm^2), plant height (cm), cob length (cm), number of grains cob^{-1}, 500 grain weight (g), biological yield (t ha^{-1}) and economics of different weed control techniques and cost benefit ratio (CBR).

Weed density and dry biomass data were recorded 75 days after sowing (DAS). Each time quadrate having size 0.5 x 0.5 m^2 was placed randomly three times in each treatment and the weeds inside the quadrate were counted. While to record the dry biomass data, quadrate was randomly thrown at three places in each treatment and the weeds inside each quadrate were harvested, and then oven dried for 48 hours at 70 ^{0}C. Average dry weight was calculated and then was converted into m^2.

Leaf area was calculated by measuring the width and length of top, middle and bottom leaves from three randomly selected plants from each treatment and then were averaged. Data recorded were multiplied by factor 0.75.

For recording the grain yield data, two central rows were harvested in each treatment bundled, sun dried and weighed. The data were then converted to kg ha^{-1} by using the following formula and then converted to t ha^{-1} subsequently.

$$\text{Biological yield (kg ha}^{-1}) = \frac{\text{Weight of sample (kg)}}{\text{Area harvested (m}^2)} \times 10{,}000$$

To calculate the cost of weed control, the cost of each treatment was determined and then compared with each other according to the prevailing market prices of maize grains.

Cost-benefit ratio (CBR) was determined by dividing the added income by added cost. The added income was obtained from the added yield due to the use of herbicide as compared to the weedy check. While the added cost was the cost of control measures used. The cost benefit ratio was calculated by the following formula.

$$\text{Cost benefit ratio (CBR)} = \frac{\text{Added income}}{\text{Added cost}}$$

The data recorded were statistically analyzed using MSTATC Software. The purpose of analysis of variance was to determine the significant effect of treatments on weeds and maize. LSD test at 5% probability level was applied for mean separation of significant parameters (Steel and Torrie, 1980)

RESULTS AND DISCUSSION

Weed density (m^{-2}) 75 days after sowing

Statistical analysis of the data depicted that weed density 75 days after sowing (DAS) was significantly affected by integrated weed management techniques. Data presented in Table-1 indicated that maximum (248.50 m^{-2}) weed density 75 days after sowing (WAS) was recorded in weedy check + low population which was at par with weed density of 240.10 m^{-2} recorded in weedy check + high population. The minimum weed density 75 days after sowing (50.80 m^{-2}) was recorded in pendimethaline 330E + medium population + weeding 6 WAS. These results depicted that pendimethaline combining with medium maize population and weeding at 6 weeks after sowing effectively controlled the weeds. The weed density in weedy check + medium population, weeding 8 WAS + low population, weeding 6 WAS + medium population and weeding 4 WAS + high population was close to maximum value. The respective values were 188.1, 158.7, 128.3 and 138.5 m^{-2}, respectively. Similarly the weed density in pendimethaline + weeding 8 WAS +low population, pendimethaline + weeding 4 WAS + high population, pendimethaline + low population, and pendimethaline + medium population were close to minimum value. The respective values were 97.40, 92.13, 118.0 and 110.9 m^{-2}. These results are in agreement with Khan *et al.* (2002) and Ali *et al.*, (2003). They reported that weed control methods significantly affected weed density m^{-2}. The present results suggest that as grassy weeds were dominant in the experimental field, therefore majority of the weed seed germination occurred within 25 days and after 75 DAS, there was not a detectable increase in the weed density. Overall pendimethaline showed better results in controlling weeds. Similar results were also reported by Tasco *et al.*, (2006). They reported that pre-emergence herbicides were excellent in controlling jimsonweed.

Dry biomass g m^{-2} 75 days after sowing

The ANOVA indicated that weed biomass was significantly affected by different treatments. Numeric values presented in Table-1 indicated that maximum (407.2 g m^{-2}) dry weed biomass was recorded in weedy check + low population in 75 DAS, while minimum weed biomass (168.2 g m^{-2}) was achieved in pendimethaline 330 E + medium population + weeding 6 WAS after 75 DAS which was at par with pendimethaline + low population+ weeding 8 WAS (188.2m^{-2}) and pendimethaline + high population + weeding 4 WAS (179.1m^{-2}) [Table-1]. These results show that pendimethaline +high population +weeding 4 WAS, and pendimethaline + low population +weeding 8 WAS controlled the dry weed biomass after 75 DAS effectively. The dry weed biomass in weedy check + medium population, weedy check + high population, weeding 8 WAS+ low population and weeding 4 WAS + high population were close to maximum value having the values of 363.6, 357.4, 286.5, 258.0 and 255.3 g m^{-2}, respectively. Similarly, the values in pendimethaline +low population, pendimethaline + medium population and pendimethaline + high population were close to the minimum value. The values were 221.8, 199.6 and 217.1 g m^{-2}. These results are in agreement with Shakoor *et al.* (1986), who reported that dry biomass of weed from the weedy control plots was significantly greater than chemical and manual weeded plots. Hafeezullah (2000) also reported similar results. He concluded that dry weight of weeds was significantly affected by different herbicidal treatment. Herbicide application decrease the dry biomass of weeds however this decreasing trend is dependent on several factors e.g. type of weed species, herbicides etc (Gonzalez and Salas, 1995).

Leaf area (cm^2)

Statistical analysis of the data revealed that leaf area was significantly affected by different treatments. Perusal of the data shown in Table-1 revealed that maximum leaf area (2944 cm^2) was recorded in pendimethaline 330 E + medium population + weeding 6 WAS, while minimum leaf area (1581 cm^2) was recorded in weedy check + low population. Leaf area (2055 cm^2) recorded in pendimethaline 330 E + low population which was statistically at par with leaf area (2090 cm^2) recorded for pendimethaline 330 E + high population + weeding 4 WAS. However leaf area (1627 cm^2) was recorded for weedy check + medium population was very close to minimum leaf area (1581 cm^2) recorded for weedy check + low population. Similarly leaf area of 1840 cm^2 was recorded for pendimethaline 330 E + high population and 1940 cm^2 was recorded for pendimethaline 330 E + medium population. The present results showed that maize plant population as well as herbicides greatly affects the leaf area of maize. Khan *et al.* (2002) got similar results. They concluded that maximum leaf area of maize was noted in those treatments where weeds were controlled. In a similar study Akhtar *et al.* (1984) reported that maximum leaf area was recorded in manually weed-controlled plots at tasseling. Leaf is the food manufacturing factory of plants and thus plays a vital role in regulating the plant growth and development. Thus any change in leaf area is an indicator hence, grain yield of maize can be predicted based on its leaf area, orientation etc.

Plant height (cm)

Statistical analysis of the data showed that plant height was significantly affected by different treatments. Maximum plant height (215.3 cm) was recorded in pendimethaline 330 E + medium population + weeding 6 WAS which was at par with (212.3 cm) recorded in pendimethaline 330 E + high population + weeding 4 WAS. Similarly minimum plant height (172.3 cm) was noted in weedy check + low population. Plant height (172.7 cm) recorded for weedy check + high population were statistically close to minimum plant height (172.3 cm) which was observed for weedy check + low population. However plant height (200.7 cm) recorded for pendimethaline 330 E + low population and plant height (205.3 cm) recorded for pendimethaline 330 E + medium population, Pendimethaline 330 E + low population + weeding 8 WAS were very close to each other (Table-1). Plant height is the function of genetic as well as environmental conditions. The difference in plant height is attributed to various intensities of weed competition with maize plant. Kamel *et al.* (1983) got similar results in a field study. Overall the data presented in Table-1 depicted that taller plants were recorded in the treatments where pendimethaline was applied. This may be due to fact that application of pendimethaline controlled the weeds during the early stage of crop growth therefore the available nutrients were used by the crop plants and thus received more nutrients and light which ultimately resulted in taller plants.

Cob length (cm)

ANOVA indicated that cob length was significantly affected by different treatments. Maximum cob length (15.75 cm) was recorded in Pendimethaline 330 E + medium population + weeding 6 WAS. However, the values of pendimethaline + medium population, pendimethaline + low population, weeding 4 WAS + high population and weeding 6 WAS + medium population were statistically at par with the maximum values. The respective values were 15.12, 14.70, 14.57 and 14.58 cm, respectively. While minimum (12.19 cm) cob length was recorded in weedy check + high population (Table-1). These results confirm the interspecific and intraspecific competition. The numerical values of cob length that were close to minimum were in pendimethaline + high population, pendimethaline + low population + weeding 8 WAS and weedy check + low population. Overall results indicate that application of herbicides increased the cob length due to effective control of weeds. As the major weeds infesting the experimental fields were *Cyperus rotundus* which is competitive weed at initial stage of the crop plants therefore the crop growth was severely affected which ultimately affected the cob length. Analogous results were reported by Kamel *et al.* (1983). They reported that weed control treatments improved cob length.

Number of grains cob^{-1}

Number of grains is an important yield contributing trait and can greatly affect the economic return. It was observed that number of grains cob^{-1} was significantly affected by different treatment assigned to different plots. It could be inferred from the data in Table-1 that maximum (544.67) number of grains cob^{-1} was obtained in pendimethaline 330 E + medium population + weeding 6 WAS, which was statistically similar with pendimethaline 330 E + high population + weeding 4 WAS (540.00). Minimum (412.1) grains cob^{-1} were recorded in weedy check + low population followed by 430 and 436.02 grains cob^{-1} recorded in weedy check + high population and weedy check + medium population, rspectively. The number of grains cob^{-1} ranged from 544.67 to 412.1. Khaliq *et al*., (2005) tested the efficacy of some herbicides for controlling weeds in maize (*Zea mays* L.) and reported that plots treated with both formulations of pendimethaline gave maximum weed control and produced relatively more number of grains cob^{-1}.

500-grain weight (g)

Grain weight greatly affects the final economic yield of a crop. Analysis of the data showed significant differences for all the treatments tested. Perusal of the data presented in Table-1 show that maximum 500-grain weight (119 g) was recorded in pendimethaline 330 E + medium population + weeding 6 WAS, followed by pendimethaline + high population + weeding 4 WAS and pendimethaline + low population + weeding 8 WAS. The respective values were 118.3 and 117.3, respectively. While minimum 500-grain weight (111.7 g) was recorded in weedy check + low population followed by weedy check + medium population where the value recorded was 112 g. Similarly 500 grain weight in all other treatments were close to one another. In those treatments where the weeds were controlled, 500 grain weights were greater as compared to un-controlled treatments as weeds share the resources with the crop plants. These results were in agreement with Janjic *et al.,* (1983) and Khan *et al.,* (2002). They reported that weed infestation decreased the 500-grain weight in maize.

Biological yield (t ha^{-1})

Biological yield is the net photosynthetic material and contributes significantly towards economic yield. Analysis of the data showed that biological yield was significantly ($p \leq 0.05$) affected by different treatments. The data presented in Table-1 indicated that maximum biological yield (9.167 t ha^{-1}) was recorded in pendimethaline 330 E + medium population + weeding 6 WAS, which was at par with pendimethaline 330 E + high population + weeding 4 WAS (9.127 t ha^{-1}). The minimum biological yield (7.827 t ha^{-1}) was recorded in weedy check + low population. Biological yield in all other treatments remained between these two values. However, they were statistically different. As all vegetative parameters were significantly affected by different treatments, the biological yield was also significantly affected. Because leaf area, number of leaves plant^{-1}, plant height, ear length and number of grains cob^{-1} contribute in increasing the biological yield. Kamel *et al.* (1983) also reported similar results. Although there was a great variation in the plant population yet, the values of biological yield were close to each other. This can be explained by the fact that at higher plant population, the vegetative parts were reduced while at lower density the crop plants attained greater vegetative growth.

Economic Analysis

Economic analysis of the integrated weed management practices in maize is shown in Table-2. Higher gross income was recorded in pendimethaline 330 E + medium population + weeding 6 WAS (Rs. 36130) followed by pendimethaline 330 E + high Population + weeding 4 WAS (Rs.34070). Variable cost was higher for pendimethaline 330 E + high population + weeding 4 WAS (Rs.3539) followed by pendimethaline 330 E + medium population + weeding 6 WAS (Rs. 3470). In the same manner, pendimethaline 330 E + medium population + weeding 6 WAS fetched higher net income (Rs. 32660) followed by Pendimethaline 330 E + high population + weeding 4 WAS (Rs.30531). Unlikely maximum cost benefit ratios (CBR) was recorded for pendimethaline 330 E + medium population (1:11.4) followed by pendimethaline 330 E + low population (1:9.2). The higher CBR in pendimethaline 330 E + medium population and pendimethaline 330 E + low population was mainly due to higher gross income and less variable cost in the same treatments. The lower CBR in pendimethaline 330 E + high population + weeding 4 WAS and pendimethaline 330 E + medium population + weeding 6 weeks after sowing (WAS) was due to the higher variable cost in the same treatments.

Table-1. Weed density and dry biomass g m^{-2} (75 DAS) and maize related traits as affected by different treatments in maize.

Treatments	Weed density 75 DAS	Dry biomass 75 DAS	Leaf area (cm^2)	Plant height (cm)	Cob length (cm)	Number of grains cob^{-1}	500 grain Weight (g)	Biological yield (t ha^{-1})
Pendimethaline 330 E + high Population	121.6 ef	217.1 e	1840 bcde	191.0 bcd	13.32 ef	462.00 e	116.3 bc	8.327 d
Pendimethaline 330 E + Medium Population	110.9g	199.6 ef	1940 bcd	205.3 ab	15.12 ab	499.33 c	116.0 c	8.487 c
Pendimethaline 330 E + Low Population	118.0 fg	221.8 de	2055 bc	200.7 abc	14.70 abc	481.67 d	115.3 cd	8.640 b
Pendimethaline 330 E + high Population + weeding 4 WAS	92.13 h	179.1 f	2090 bc	212.3 a	13.46 cde	540.00 a	118.3 ab	9.127 a
Pendimethaline 330 E + Medium Population + weeding 6 WAS	50.80 i	168.2 f	2944 a	215.3 a	15.75 a	544.67 a	119.0 a	9.167 a
Pendimethaline 330 E + low Population + weeding 8 WAS	97.40 h	188.2 ef	2125 b	205.3 ab	13.28 ef	521.33 b	117.3 abc	8.273 e
Weeding 4 WAS + high Population	138.5 d	255.3 cd	1794 cde	180.3 d	14.57 abcd	452.21 f	115.3 cd	8.237 e
Weeding 6 WAS + medium Population	128.3 e	258.0 c	2001bc	184.7 cd	14.58 abcd	461.00 e	115.7 cd	8.710 b
Weeding 8 WAS + low Population	158.7 c	286.5 c	1654 de	180.0 d	13.45 de	444.31 g	115.3 cd	8.663 b
Weedy check+ high Population	240.1 a	357.4 b	1841bcde	172.7 d	12.19 f	430.00 h	113.7 de	8.620 b
Weedy check + Medium Population	188.1b	363.6 b	1627de	175.3 d	14.23 bcde	436.02 h	112.0 e	8.480 c
Weedy check + Low Population	248.5 a	407.2 a	1581e	172.3 d	13.03 ef	412.1 I	111.7 e	7.827 f
LSD $_{0.05}$	10.22	35.52	323.4	18.87	1.245	2.139	2.191	0.734

WAS = Weeks after sowing, DAS = days after sowing

Value followed by different letters are significantly different at 5% level of probability.

Table-3. Economics and Cost benefit ratio of different treatments.

Treatments	Gross Income (Rs.)	Variable Cost (Rs.)	Net benefits (Rs.)	Cost Benefit Ratio
Pendimethaline 330 E + high Population	27770	529	27241	1:4.5
Pendimethaline 330 E + Medium Population	30430	460	29970	1:11.4
Pendimethaline 330 E + Low Population	27870	390	27480	1:9.2
Pendimethaline 330 E + high Population + weeding 4 WAS	34070	3539	30531	1:2.4
Pendimethaline 330 E + Medium Population + weeding 6 WAS	36130	3470	32660	1:3.2
Pendimethaline 330 E + low Population + weeding 8 WAS	28730	3400	25330	1:1.3
Weeding 4 WAS + high Population	25900	3209	22691	1:0.2
Weeding 6 WAS + medium Population	31030	3140	27890	1:1.9
Weeding 8 WAS + low Population	27800	3070	24730	1:1.1
Weedy check + high Population	25400			
Weedy check + Medium Population	25170			
Weedy check + Low Population	24300			

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