Pak. J. Weed Sci. Res. 17(4): 333-342, 2011

EVALUATION OF HERBICIDES FOR WEED MANAGEMENT IN MAIZE AND THEIR IMPACT ON MAIZE GRAIN YIELD

Zahid Hussain[1], Fazal Munsif[2], Kawsar Ali[2], Syed Ishfaq Ali Shah[3] and Abdur Rahman[4]

ABSTRACT

Different herbicides were evaluated against the hand weeding and weedy check, for weed competition and grain yield of maize. The experiment was carried out at the Agricultural Research Institute (Tarnab) Peshawar, during the maize growing season 2009. The experiment was laid out in randomized complete block design with three replications using the maize variety "Azam" with a seed rate of28 kg ha^{-1}. Seven different herbicides were applied at their recommended rates. The treatments applied were atrazine + s-metolachlor (Primextra Gold 720SC as standard), atrazine (Atarazine 38 SC as standard), s-metolachlor (Dual gold 960 EC as stand.), atrazine + propisochlor (Weed out 720SC as candidate), butachlor (Client 90% EC as cand.), acetochlor (Appeal 99% EC as cand.), acetochlor (Acetor 50% EC as cand.), a hand weeding and a weedy check treatment. Data was collected on weed density m^{-2}, mortality percentage, fresh weed biomass, maize grain yield and grain yield. All the treatments significantly affected the checked parameters. The hand weeding treatment has been mostly successful in all parameters however it was overtaken by Primextra gold 720 SC in the cost benefit ratio. Like the hand weeding treatment, all the herbicides considerably affected weeds density and reduced their population to a significant level as compared to the weedy check treatments. Luckily, no crop injury was observed in any of the herbicide treatments. The mortality percentage of weeds ranged between 74.94 – 81.84%, whereas hand weeding showed 97.2%. Acetor 50% EC and Primextra gold 720SC showed the best performance in weeds mortality percentage. Similarly, the weed biomass in the herbicide treatments ranged between 1032 – 1416 kg ha^{-1}. However, lowest weed biomass was found in hand weeding and highest in weedy check treatments. Highest grain yield of maize was achieved in hand weeding and in contrary lowest grain yield in weedy control plots. The overall increase in yield by the herbicides over weedy control was found from 13.94 to 22.08%. Herbicides thus by reducing the weed density and biomass increased the grain yield of maize. Hand weeded treatments fetched highest gross income and added income followed by Acetor 50EC and Primextra gold 720 SC treatments. However, maximum CBR was calculated for Primextra gold 720SC followed by Acetor 50EC and Atrazine 38 SC treatments. The CBR calculated in the hand weeded treatments was though the lowest. Primextra gold 720 SC and Acetor 50 EC are therefore recommended for effective weed control as pre

[1]Department of Weed Science, [2]Department of Agronomy, [4]Livestock Management Department, KPK Agricultural University Peshawar, [3]Central Crops Research Institute, Multan, Pakistan. Corresponding author: zhussainws@aup.edu.pk.

emergence and post emergence herbicide respectively for maize economic yield in Peshawar valley.

Key words: Economic analysis, impact, grain yield, herbicides, maize, weed control, weeds.

INTRODUCTION

Maize *(Zea mays* L.) plays an important role in the economy of Pakistan. In spite of the best efforts and intensive research, maize yields in Pakistan are much lower than their potential yields. Weeds cause reduction in crop yields by competing for light, nutrients, water and carbon dioxide and interfere in farm operations besides increasing the cost of production. In addition, weeds harbour insects and plant disease organisms and in some cases, they serve as alternate host for insect pests and disease organisms; thus indicating that weeds are the most persistent of all crop pests.

There are a number of ways to control weeds; however looking at the economics of the concerned farmers and quick action for a weed free environment, the chemical weed control method is still very popular in developing countries. The cultural methods are described to be useful for safe environment but are getting expensive, laborious and time consuming. Chemical weed control if properly implemented and judiciously utilized is quite effective and efficient method having less harm to the environment concerned. Weed control in maize with herbicides have been suggested by many researchers (Shakoor *et al.,* 1986; Correa *et al.,* 1990; Owen *et al.,* 1993). The battle against weeds is a perpetual struggle, not for a day or two. Implementing an integrated pest management (IPM) program is the best way to meet weeds head on. An IPM program will operate a multi-faceted plan of attack including herbicides use, removing some of the stubborn ones by hand and exploiting other weed control tools for an all encompassing and environmentally sound weed control program.

Shortage of labor for weed removal is an important production constraint in farms (Weber *et al*., 1995). In addition, the time of herbicide application is the key for success in weed control. Weed control in maize after the critical period of weed removal can result in up to 83% losses in grain yield (Usman *et al*., 2001). The most critical period of weed competition is during the first four to six weeks after emergence of the crop (Zafar *et al*., 1981). If crops are kept weed-free during the early stages, yields will not be affected significantly. At later stages the maize plants will be well established and out-compete the weeds. Although early weeding is critical to producing a good yield, late control is also important in preventing the weeds from flowering and producing seeds, which would affect the crop and increase weed load in subsequent seasons. Harvesting will also be made easier if the

crop is weed free. It has a positive impact on tassels (male inflorescence) and ears, the female inflorescence (Khalil and Jan, 2004).

Plots kept free for the first six weeks yield as high as plot kept weed free for the entire season (Khalid and Shad, 1987). Atrazine is one of the key herbicides for weed management in maize. Ndahi (1984) tested atrazine at rate of 1 kg ha^{-1} supplemented with one hand weeding and reported that this treatment gave yields comparable to the weed free control. Shakoor *et al*., (1986) reported that atrazine at the rate of 3 kg ha^{-1} applied as pre-emergence reduced the weed population by 94% and increased the grain yield by 1436 kg ha^{-1} over the weedy control. Malik *et al*. (2006) reported that herbicides have a good impact on maize yields by effectively managing weeds. The use of herbicides should however be constructive to the concerned soil, crop, weeds and stage of crop development. For instance, after the maize seed has been planted, atrazine can be applied to kill the weeds before they emerge. Atrazine, applied as a pre-emergence herbicide, controls most annual broadleaf weeds and some annual grasses. It is only recommended for use on soil with more than 35% clay (Khan and Haq, 2004).

Farmers should become familiar with the types of weeds present in their fields. For instance, broadleaf weeds should be distinguished from grasses. The farmer needs to learn which weeds are annuals (i.e. live for only one season) or perennials (i.e. live for more than one year). This will help control the weeds effectively, especially when chemicals are used. The study was therefore, planned to evaluate the effect of different pre- and post-emergence herbicides application on weeds mortality and maize yields, to compare the effects of candidate products with standard herbicides for weed control and maize grain yield, and also to find out the most economical and effective herbicide for weed control in maize. The present study was also designed for the development of an integrated weed control system in maize.

MATERIALS AND METHODS

An experiment on evaluation of different herbicides for weed control in maize was conducted at ARI (Agriculture research institute, Tarnab Peshawar during Kharif season 2009. The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications using the maize variety “Azam” with a seed rate of 30 kg ha^{-1}. A plot size of 5m x 3m was kept for each experimental unit. The experiment consisted of eight treatments replicated three times. Seedbed was prepared with the help of disc plough followed by planking twice. Recommended doses of urea and DAP were applied at proper times. Irrigations were done five times in the season as per requirement.

The crop was sown on a silty clay loam soil. The experimental site had a mean soil pH of 8.02 having 40% clay, 51.3% silt and 8.7% sand (Bhatti, 2002; Tariq *et al*., 2002). The pre-emergence herbicides were applied on two days after sowing; whereas the post emergence herbicides were applied when weeds have emerged. The herbicides were sprayed with the help of knap sack sprayer cp-3 fitted with four flat fan 8003 number nozzles on a specially made boom, directed post-emergence sprays using polijet tips with a shield employed for knap sack spraying. Drift was minimized by using these nozzles with shield.

The data on various parameters were recorded during the course of studies following standard procedures. Data on weed density m^{-2} were collected two weeks after herbicide application using a quadrate of size 1m x 1m. The quadrate was randomly thrown three times each in the treatments and averages were computed then. Initial weed population was recorded just before spraying. The second weed population was recorded twenty days after herbicides spray to calculate mortality percentage. For data on weed biomass, weeds between the mid three rows of each treatment were removed, gathered and weighed with a digital balance in grams. The values were then converted into kg ha^{-1}. Grain yield data were taken by selecting the mid three rows in each treatment, harvesting them at the physiological maturity and threshing the cobs after storage for a couple of weeks. The following was the detail of the treatments in the experiment.

S.N.	**Treatments (trade names)**	**Common Names**	**Application Time**	**Rate L ha^{-1}**
1.	Primextra Gold 720SC (stand.)	atrazine + s-metolachlor	Pre emergence	2.00
2.	Atarazine 38 SC (stand.)	Atrazine	Post emergence	1.25
3.	Dual gold 960 EC (stand.)	s-metolachlor	Pre emergence	1.50
4.	Weed out 720SC (cand.)	atrazine + propisochlor	Pre emergence	1.63
5.	Client 90% EC (cand.)	Butachlor	Post emergence	1.38
6.	Appeal 99% EC (cand.)	Acetochlor	Post emergence	0.63
7.	Acetor 50% EC (cand.)	Acetochlor	Post emergence	1.25
8.	Hand weeding	---	---	---
9.	Weedy Check	---	---	---

In order to minimize the masking effect of one herbicide on the other, a buffer zone equivalent to two additional rows was planted to separate the two adjacent plots. The cultural practices were kept uniform and according to the recommendations.

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.

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

The data collected were analyzed statistically by using appropriate statistical methods (Steel *et al*., 1997). All the data taken were analyzed statistically according to the appropriate statistical technique and the significant means were separated using LSD test.

RESULTS AND DISCUSSION

Weed density m^{-2} / Mortality percentage

Statistical analysis of the data related to weed density m^{-2} and different weed flora (Table-1) indicated that the herbicides and hand weeding treatments considerably suppressed the weeds densities. As expected the hand weeding treatment significantly reduced the weed density to 2.4 weeds m^{-2}. All the herbicides reduced weed populations considerably over the check. The rest of the herbicides Acetor 50% EC, Primextra gold 720 SC, Appeal 99 EC (cand.), Dual gold 960 EC, Client 90 EC (cand.), Weed out 720 SC, Atrazine 38 SC decreased the weed density to 15.8, 18, 20.0, 20.3, 21.7, 21.8 and 22.1 weeds m^{-2}, respectively. Thus herbicides considerably affected weeds and reduced their population to a significant level as compared to the weedy check treatments, where maximum weed density of 87 plants m^{-2} was recorded. However, the herbicides had statistically at par effect on weed densities. In addition, no crop injury was observed though by any of the herbicides. As far as the mortality percentage of weeds was concerned, the best performance was of hand weeding treatments with 97.24% reduction in weeds population. The mortality of weeds due to the herbicides ranged between 74.94 – 81.84%. The best activity was that of Acetor 50% EC with 81.84% weeds mortality percentage. The mortality percentage of weeds in Table-1 indicated that weed population was convincingly decreased by the application of different herbicides. The herbicides selected as standard treatments were those

which were popular among farmers for weed control in maize. The candidate herbicides were to be tested for comparison with the standards for registration submitted by different pesticide companies.

Table-1. Weed density m^{-2} as affected by weed control treatments in maize.

Treatments	Cr	Av	Ca	Cd	Sh	Ds	Ec	Tp	Total weeds	Mortality %age
Primextra Gold 720SC (stand.)	3.4	1.7	1.3	2.0	3.2	3.1	1.6	1.7	18.0 c	79.31
Atarazine 38 SC (standard)	4.3	2.5	2.0	1.8	3.8	3.6	2.0	2.1	22.1 c	74.59
Dual gold 960 EC (standard)	3.9	3.0	2.0	1.8	2.9	2.9	1.8	2.0	20.3 c	76.67
Weedout 720SC (candidate)	3.9	3.1	2.0	2.2	3.2	3.0	2.0	2.4	21.8 c	74.94
Client 90% EC (candidate)	4.2	2.9	1.9	2.0	3.1	3.2	2.3	2.1	21.7 c	75.06
Appeal 99% EC (candidate)	3.8	2.6	1.8	1.8	3.0	3.0	2.0	2.0	20.0 c	77.01
Acetor 50% EC (cand.)	4.0	2.2	1.5	2.6	2.0	1.2	1.3	1.0	15.8 c	81.84
Hand weeding	0.3	0.2	0.2	0.4	0.4	0.4	0.3	0.2	2.4 b	97.24
Weedy Check	12.3	14.0	9.3	9.7	10.8	12.7	7.0	11.2	87.0	---
LSD	---								12.7	---

Means sharing the same letter do not differ significantly by LSD at 5 % probability level.
Cr = *Cyperus rotundus*, Av = *Amaranthus viridis*, Ca = *Convolvulus arvensis*, Cd = *Cynodon dactylon*, Sh = *Sorghum halepense*, Ds = *Digitaria sanguinalis*, Ec = *Echinochloa crus-galli*, Tp = *Trianthema portulacastrum*.

Fresh weed biomass (kg ha^{-1})

The data regarding fresh weed biomass is presented in Table-2. The parameter was significantly influenced by the applied hand weeding and herbicide treatments. The following weeds were found in the experiment treatments i.e. *Cyperus rotundus*, *Amaranthus viridis*, *Convolvulus arvensis*, *Cynodon dactylon*, *Sorghum halepense*, *Digitaria sanguinalis*, *Echinochloa crus-galli* and *Trianthema portulacastrum*. The highest weed biomass was recorded in the weedy check plots (3402 kg ha^{-1}), which was significantly higher than the herbicide treatments. The weed biomass was lowest (268 kg ha^{-1}) in the hand weeding treatments. Among the herbicides, the weed biomass was greatly affected by Acetor 50EC (candidate herbicide) with 881 kg ha^{-1} weed biomass. The weed biomass in the rest of the herbicide treatments ranged between 1032 – 1416 kg ha^{-1}. These results are in consonance with the findings of Khan and Haq (2004) and Khan *et al*.

(2003) who reported significant decrease in weed biomass by application of herbicides. Generally an increase in one kilogram of weed growth corresponds to a reduction in one kilogram of crop growth (Rao, 2000), as the resources of land, water and nutrients are equally shared by weed and crop plants in which weeds are more efficient.

Table-2. Weeds fresh biomass, maize grain yield (kg ha^{-1}), and yield increase over weedy check as affected by weed control treatments.

Treatments	Weed biomass (kg ha^{-1})	Grain yield (kg ha^{-1})	Increase in Yield over WC (kg ha^{-1})	% increase in yield
Primextra gold 720SC(St.)	1032 d	3986 bc	824	20.67
Atarazine 38 SC (St.*)	1385 bc	3674 c	512	13.94
Dual gold 960 EC (St.)	1244 c	3788 c	626	16.53
Weed out 720SC (Can.)	1416 b	3710 c	548	14.77
Client 90% EC (Can.)	1310 bc	3717 c	555	14.93
Appeal 99% EC (Can.)	1155 cd	3890 bc	728	18.71
Acetor 50% EC (Can.)	881 e	4058 ab	896	22.08
Hand weeding	268 f	4219 a	1051	24.91
Weedy Check (WC)	3402 a	3162 d	---	---
LSD	149	230		

*St. = Standard, Can. = Candidate

Means not sharing a letter differ significantly by LSD at 5% probability level.

Grain yield (kg ha^{-1})

The grain yield of maize was significantly affected by the different herbicides treatments. The highest grain yield of 4219 kg ha^{-1} was obtained from the plots of hand weeding with 24% increase over check; weedy check had a minimum grain yield of 3162 kg ha^{-1}. The hand weeding treatments was followed by the herbicides, Acetor 50% EC (candidate), Primextra Gold 720SC (standard), and Appeal 99% EC (candidate) with grain yields of 4058, 3986, and 3890 kg ha^{-1}, respectively; however they were statistically at par. These herbicides increase maize grain yield by 22.08, 20.67, and 18.71%, respectively as compared to weedy check treatments. Excluding the hand weeding, the overall increase in yield by the herbicides over control was found from 13.94 to 22.08%. It has become obvious from the saying of Rao (2000) that weed growth and crop growth are inversely proportional to each other i.e. the lower the weed biomass is the higher the crop yield will be. Herbicides thus by reducing the weed density and biomass increased the grain yield of maize. These results are in consistency with the findings of Ullah *et al*. (2008) and Ali *et al*. (2003) who reported significant increase in grain yield of maize with the application

of herbicides. Similarly, Khan and Haq (2004) and Khan *et al*. (2003) also got analogous results.

Economic Analysis

Economic analysis of the weed management practices in maize is shown in Table-3. Highest gross income of Rs. 84380 was recorded in hand weeded treatments, followed by Rs. 81160 in Acetor 50EC treatments and Rs. 79720 in Primextra gold 720 SC treatments. Hand weeded treatments fetched highest added income of Rs. 21020 followed by Acetor 50EC (Rs. 17920) and Primextra gold 720 SC treatments (Rs. 16480). Unlikely maximum cost benefit ratios (CBR) was recorded for Primextra gold 720SC (1:7.5) followed by Acetor 50EC (1:6.2) and Atrazine 38 SC treatments (1:5.4). The lowest CBR (1:2.9) was calculated in the hand weeded treatments. The higher CBR in Primextra gold was due to higher gross income and less cost in the same treatments. The lowest CBR in hand weeding treatments was by reason of the higher added cost (labor cost) in the same treatments.

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

Treatments	Gross income (PKR)	Added income (PKR)	Added cost (PKR)	Cost Benefit Ratio
Primextra gold 720SC (St.)	79720	16480	2119	1:7.5
Atarazine 38 SC (St.*)	73480	10240	1896	1:5.4
Dual gold 960 EC (St.)	75760	12530	2610	1:4.8
Weed out 720SC (Can.)	74200	10960	2490	1:4.4
Client 90% EC (Can.)	74340	11100	2642	1:4.2
Appeal 99% EC (Can.)	77800	14560	2971	1:4.9
Acetor 50% EC (Can.)	81160	17920	2890	1:6.2
Hand weeding	84380	21020	7248	1:2.9
Weedy Check (WC)	63240	---	---	---
Rs. kg^{-1} of maize	20 (Year 2008-09)			

CONCLUSION

The hand weeding treatment has been mostly successful in all respects except cost benefit ratio where it was exceeded by Primextra gold herbicide. Regardless of the hand weeding, the applied herbicides considerably affected weeds and reduced their population to a significant level as compared to the weedy check treatments. Interestingly no crop injury was observed in any of the herbicide treatments. The mortality percentage of weeds ranged between 74.94 – 81.84% excluding the hand weeding. The best activity was that of Acetor 50% EC in weeds mortality percentage. The weed biomass was lowest in the hand weeding and highest in weedy check plots. The weed biomass in the herbicide treatments ranged between 1032 – 1416 kg ha^{-1}. Grain yield of maize was highest in hand weeding and

weedy check in contrary produced lowest grain yield. The overall increase in yield by the herbicides over weedy control was found from 13.94 to 22.08%. Herbicides thus by reducing the weed density and biomass increased the grain yield of maize. Hand weeded treatments fetched highest gross income and added income followed by Acetor 50EC and Primextra gold 720 SC treatments. Unlikely maximum CBR was calculated for Primextra gold 720SC followed by Acetor 50EC and Atrazine 38 SC treatments. The lowest CBR was calculated in the hand weeded treatments. For effective and economic weed control in maize Primextra gold 720 SC and Acetor 50EC are recommended as a pre emergence and post emergence herbicides respectively.

REFERENCES CITED

Ali, R., S.K. Khalil, S.M. Raza and H. Khan. 2003. Effect of herbicides and row spacing on maize (*Zea mays* L). Pak J. Weed Sci. Res. 9(3-4): 171-178.

Bhatti, A.U. 2002. Soil fertility status of Malakandher Farm. Soil Bull. 6. Dept. Soil and Env. Sci., NWFP Agricultural University Peshawar, Pakistan.

Correa, A.J.A, M.M. De-Larosamora and Y.J.A. Dominguez. 1990. Demonstration plots for chemical weed control in rainfed maize *(Zea mays* L.) sown with minimum tillage in Acolmn Mexico Revista Chapingo. 15: 164-166.

Khalid, S. and R.A. Shad. 1987. Weed crop competition: *Sorghum halepense* as a competitive weed in maize. *In*: advances in weed science, a case of indo pakistan subcontinent (R. A. Shad ed.) 145 150. Proc. Pak-Indo-US Weed Cont. Workshop, March, 11-14, Islamabad.

Khalil, I.A. and A. Jan. 2004. Cereal crops cropping technology. National Book Foundation, Islamabad. pp. 169-201.(please check this reference, it may need correction)

Khan, M. and N. Haq. 2004. Weed control in maize (*Zea mays* L.) with pre and post-emergence herbicides. Pak. J. Weed Sci. Res. 10(1-2): 39-46.

Khan, M.A., K.B. Marwat, N. Khan and I.A. Khan. 2003. Efficacy of different herbicides on the yield and yield components of maize. Asian J. Plant Sci. 2(3): 300-304.

Malik, M. A., F. Zahoor, S. H. Abbas and M. Ansar. 2006. Comparative study of different herbicides for control of weeds in rainfed maize (*Zea mays* L.). WSSP Absts. Weed Sci. Soc. Pak. 62p.

Ndahi, W.B. 1984. Evaluation of herbicides for maize production in the ecological zones of Nigeria. Trop. Pest Manage. 30 (4): 356-359.

Owen, M.D.K., R.G. Hartzler and J. Lux. 1993. Wooly cupgrass *(Eriochloa Villosa)* control in corn *(Zea. mays* L.) with Chloro-acetamide herbicides. Weed Technol. 7: 925-929.

Rao, V.S. 2000. Harmful effects caused by weeds. Principles of Weed Science. Oxford and IBH publishing Co. Pvt. Ltd. New Delhi & Calcutta. Pp. 1.

Shakoor, A., M. Naeem and C.O. Ahmad. 1986. Efficacy of different herbicides for control of weeds in maize under rainfed conditions. Pak. J. Agric. Res. 7(4): 264 268.

Steel, R.G.D., J.H. Torrie and D. Dickey. 1997. Principles and Procedures of Statistics: a biometrical approach. 3rd Ed. McGraw Hill Book Co. Inc. New York. pp. 172-177.

Tariq, M., M.A. Khan and S. Parveen. 2002. Response of maize to applied soil zinc. Asian J. Pl. Sci. 1(4): 476-477.

Usman, A., K.A. Elemo, A. Bala and A. Umar. 2001. Effect of weed interference and nitrogen on yields of a maize/rice intercrop. Int. J. Pest Manage. 47: 241–246.

Ullah, W., M.A. Khan, M. Sadiq, H. Rehman, A. Nawaz and M.A. Sher. 2008. Impact of integrated weed management on weeds and yield of maize. Pak. J. Weed Sci. Res. 14(3-4): 141-151.

Weber, G., K. Elemo, and S.T.O. Lagoke. 1995. Weed communities in intensified cereal-based cropping systems of the northern Guinea savanna. Weed Res. 35: 167–178.

Zafar, M.I., R. Anwar and A.R. Saleemi. 1981. Effectiveness of chemical weed control in maize production. Pak. J. Agric. Res. 2(1): 21-23.