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Article

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Effect of Different Herbicides, Plant Extracts and Mulches on Yield and Yield Components of Maize

Efeito de Diferentes Herbicidas, Extratos de Plantas e Folhada sobre o Rendimento e os Componentes de Rendimento do Milho

ABSTRACT - To examine the effect of pre emergence herbicides, plant extracts and mulches on yield and yield components of maize, a field experiment was carried out at New Developmental Farm, The University of Agriculture Peshawar-Pakistan during summer crop season 2016. Maize variety "Azam" was sown in Randomized Complete Block (RCB) design having four replications and ten treatments i.e. hand weeding, Dual Gold 960 EC (S-metolachlor 1 L ha^{-1}), Stomp 330 EC (pendimethaline 2.5 L ha^{-1}), atrazine 1.25 L ha^{-1}, *Eucalyptus camaldulensis* L. extract (125 g L^{-1}), *Ammi visnaga* L. extract (125 g L^{-1}), black plastic mulch, wheat straw mulch, saw dust mulch and weedy check. The data revealed that hand weeding and herbicides significantly affected the weed density (m^{-2}), weeds biomass (kg ha^{-1}), plant height (cm), kernels weight (g), number of kernels ear^{-1}, biological yield (kg ha^{-1}) and grain yield (kg ha^{-1}). All the significant parameters of crop were comparable among the hand weeding, atrazine, S-metolachlor and pendimethaline treated plots. However, atrazine and S-metolachlor proved to be the most economical herbicides giving maximum yield (4636.4 and 4562.8 kg ha^{-1}), respectively. Among plant extracts, *E. camaldulensis* showed satisfactory results in suppressing weeds and enhancing yield of maize i.e. (3441.6 kg ha^{-1}). Hence, the use of herbicides (atrazine and S-metolachlor) at the recommended rates and hand weeding is recommended for effective weed control and ultimately high yield of maize crop.

Keywords: alleloplthy, *Zea mays* L., chemical control, soil cover, weeds, crop production.

*RESUMO - Para avaliar o efeito de herbicidas de pré-emergência, extratos vegetais e folhada sobre a produção e os componentes da produção de milho, foi realizado um experimento de campo na New Developmental Farm, University of Agriculture Peshawar-Pakistan, durante a safra de verão de 2016. O cultivar de milho Azam foi semeado em delineamento em blocos casualizados (DCB) com quatro repetições e dez tratamentos, ou seja, capina manual, Dual Gold 960 EC (S-metolacloro 1 L ha^{-1}), Stomp 330 EC (pendimetalina 2,5 L ha^{-1}), atrazine 1,25 L ha^{-1}, extrato de **Eucalyptus camaldulensis** L. (125 g L^{-1}), extrato de **Ammi visnaga** L. (125 g L^{-1}), cobertura plástica preta, cobertura de palha de trigo, cobertura de serragem e cobertura de plantas daninhas. Os dados revelaram que capina manual e herbicidas afetaram significativamente a densidade de plantas daninhas (m^{-2}), biomassa de plantas daninhas (kg ha^{-1}), altura de plantas (cm), peso de grãos (g), número de grãos (kg ha^{-1}) e rendimento de grãos (kg ha^{-1}). Todos os parâmetros significativos da cultura foram comparáveis entre as parcelas tratadas com capina manual, atrazina, S-metolacloro e pendimetalina. No entanto, atrazina e*

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S-metolacloro provaram ser os herbicidas mais econômicos, com rendimento máximo (4.636,4 e 4.562,8 kg ha^{-1}, respectivamente). Entre os extratos vegetais, ***E. camaldulensis*** *apresentou resultados satisfatórios na supressão de plantas daninhas e aumento na produtividade de milho (3.441,6 kg ha^{-1}). Assim, o uso de herbicidas (atrazina e S-metolacloro) nas doses indicadas e na capina manual é recomendado para o controle efetivo das plantas daninhas e, em última instância, o alto rendimento da cultura do milho.*

Palavras-chave: alelopatia, *Zea mays* L., controle químico, adubo, plantas daninhas, produção.

INTRODUCTION

Maize is the third most important cereal crop after wheat and rice. It is used for food, fodder, pharmaceutical and industrial purposes. It has great importance particularly in developing countries like Pakistan where population is rapidly increasing. In Pakistan maize was cultivated on an area of 1229 thousand hectares with an average yield of 4640 kg ha^{-1} and total annual production was 5702 thousand tons (Pakistan, 2017/2018). The average yield of maize is very low in Pakistan due to various factors. Among these factors, weeds are the major one causing an average yield loss of about 38% in maize (Hassan and Marwat, 2001).

Besides reducing yield, weeds also affect grain quality due to presence of weed seed and debris. In Pakistan, the major weeds in maize are *Trianthema portulacastrum* L., *Cyperus rotendus* L., *Echinochloa colona* L., *Sorghum halepense* L., *Digera arvensis* L. and *Cynodon dactylon* (L.) Pers. (Riazet al., 2007). The yield losses in maize as a result of weed are 16-40% (Valverde et al., 1995), while another study reported losses up to 70% (Teasdale, 1995). Various kinds of weed control methods are being used like cultural, biological, physical and chemical etc. No doubt hand weeding method is still useful but is laborious, expensive and also time consuming. Moreover, the labour difficulty is becoming acute day by day and it will not be economical to stick only to the traditional weed control techniques. Chemical weed management is an important substitute. Although weed control through the herbicides is fast and cheap as compared to other weed control methods, still it has harmful effects on environment, human health, wildlife, water bodies and soil microbes apart from development of resistance in weeds. So, the need for non-chemical and eco-friendly weed control methods has increased. One of the best choices among eco-friendly techniques is the use of bio-herbicides (allelopathy) against weeds. Many plant products are known to have the ability to inhibit germination and growth of other plants. Therefore, the plant product can be a possible alternative to synthetic herbicides and these may be used as natural herbicides (Mahmood and Cheema 2004). It is a natural and environment friendly method which may prove to be an effective weed control strategy and can result in increased crop yields (Tefera, 2002). Several researchers have reported the possibility of using allelopathy for weed control (El-Rokiek et al., 2006). It is a viable weed management strategy which needs to be studied extensively both in laboratory and in the field conditions.

Other techniques include the utilization of different types of mulches for effective weed control. Mulching is a recent and effective non-chemical weed control method (Ramakrishna et al., 2006). In mulching two types of materials i.e. organic mulch (living) and inorganic mulch (non-living) are used to cover the soil surface in order to protect and improve the covered area. Organic mulch includes leaves, barks, woodchips and grass clipping etc while inorganic mulch includes polyethylene sheaths, pebbles and gravels etc. Mulching is the best way used to control weeds (Kluepfel, 2010). It is crucial to cover the soil surface with different materials to attain high biological activity, retain soil moisture and to achieve a good control of weeds (Sturny, 1998). Mahajan et al. (2007) found out that plastic mulch resulted in enhanced yield over unmulched soil. Plastic mulch conserves soil moisture and controls weeds up to 91-100% (Awodoyin et al., 2007).

Keeping in view the importance of maize crop and losses caused by weeds, an experiment was designed to study the efficacy of different herbicides, mulches and plant extracts for weed control in maize crop; to figure out their effect on yield of maize and to select the best mulch for weed control suitable to local environment and to enhance maize production.

MATERIALS AND METHODS

The research work was conducted at New Developmental Farm, The University of Agriculture Peshawar, Pakistan during 2016. The trial was carried out in (RCB) design having four replications. Each replication had ten treatments having four rows and the size of each plot was 4 x 3 m^2. The row to row distance was kept 75 cm, while plant to plant was kept 20 cm. The treatments were S-metolachlor as pre emergence at the rate of 1 L ha^{-1}, Pendimethalin as pre emergence at the rate of 2.5 L ha^{-1}, Atrazine as pre emergence at the rate of 1.25 L ha^{-1}, *Eucalyptus camaldulensis* L. extract at the rate of 125 g L^{-1}, *Ammivisnaga*L.extract at the rate of 125 g L^{-1}, black plastic, wheat straw, and saw dust as mulch, hand weeding and weedy check.

The seed of open pollinated maize variety 'Azam' was sown with the help of planter. All recommended cultural practices and inputs including fertilizers and irrigation were applied uniformly to all entries. The dried powder of the plants samples (*E. camaldulensis*and *A. visnaga*) were weighed and soaked in water at the rate of 125 g L^{-1} to extract for 24 hrs at room temperature. The samples were filtered through muslin cloth to obtain final extracts. The filtered solutions were put in bottles and tagged for further use in the experiment. All the herbicides were applied at their recommended rate after sowing while mulches and plant extracts were applied after three weeks of sowing. Similarly control treatment was kept uninterrupted for comparing the effect of other treatments. The data were recorded on weed density (m^{-2}), fresh weed biomass (kg ha^{-1}), dry weed biomass (kg ha^{-1}), maize plant height (cm), 500 kernels weight (g), number of kernels ear^{-1}, biological yield (kg ha^{-1}), grain yield (kg ha^{-1}) and harvest index during the experiment. The data recorded were subjected to the ANOVA procedure using MSTATC computer software and means were separated by using LSD test (Steel and Torrie, 1980) at 5% level of probability.

RESULTS AND DISCUSSION

Weed density (m^{-2})

The data revealed that different treatments significantly affect the weed density (Table 1). The mean data revealed that highest weed density (194.50 m^{-2}) was recorded in weedy check treatment while the minimum weed density (27.25 m^{-2}) was obtained in hand weeding plots, followed by herbicide atrazine and S-metolachlor (48.00 m^{-2} and 52.25 m^{-2}), respectively. The overall data revealed that hand weeding and herbicides application were the most effective against the weeds among all the weed control measures. Maximum weeds m^{-2} were recorded in weedy check plots because weedy check plots were left untreated throughout the growing period. Our results are in agreement with those reported by Aslam et al. (2007), Khan et al. (2012b) and Amare et al. (2015) who found that hand weeding could effectively control weeds against weedy check.

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

The data showed that fresh weed biomass was significantly ($p \leq 0.05$) affected by different weed control measures (Table 1). The lowest fresh weed biomass (78.75 kg ha^{-1}) was observed in hand weeding plots, followed by herbicides atrazine and S-metolachlor (102.31 and 106.08 kg ha^{-1}), respectively (Table 1). The highest fresh weed biomass (323.66 kg ha^{-1}) was noticed in weedy check plots. The overall results revealed that among all the treatments, herbicides proved to be the best option for the effective weed control in maize crop. The minimum fresh weed biomass in hand weeding treated plots was due to the lowest number of weeds as a result of uprooting through weeding resulting into lowest fresh weed biomass as compared to weedy check. Our results are in line with the work of Ali et al. (2011) who reported that hand weeding and herbicides efficiently control weeds as compared to other treatments. The pre-emergence application of atrazine herbicide caused maximum decrease in the germination and biomass of weeds (Khan et al., 2012b). The lowest weed biomass in herbicide treatments might be due to the broad spectrum phytotoxic effect of herbicide on the weed growth and biomass (Patel et al., 2006).

Table 1 - The effect of different herbicides, plants extracts and mulches on weed density (m^{-2}), fresh weed biomass (kg ha^{-1}) and dry weed biomass (kg ha^{-1}) in maize

Treatment	Weed density (m^{-2})	Fresh weed biomass (kg ha^{-1})	Dry weed biomass (kg ha^{-1})
S-metolachlor	52.25 g	106.08 e	44.00 ef
Pendimethaline	62.00 f	115.03 de	48.55 e
Atrazine	48.00 g	102.31 e	42.11 f
Eucalyptus extract	153.25 c	202.00 b	72.15 b
Ammi visnaga extract	168.25 b	209.75 b	75.86 b
Black plastic mulch	67.00 f	129.24 cd	56.77 d
Wheat straw mulch	81.25 e	136.22 c	60.32 cd
Saw dust mulch	90.00 d	144.50 c	63.08 c
Hand weeding	27.25 h	78.75 f	22.70 g
Weedy check	194.50 a	323.66 a	89.85 a
LSD 0.05	7.103	16.072	5.039
CV %	5.1	7.16	6.04

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

The results shown in Table 1 revealed that lowest weed dry biomass (22.70 kg ha^{-1}) was observed in hand weeding plots, while the highest dry biomass (89.85 kg ha^{-1}) was noticed in weedy check plots. These results demonstrated that among all the tested weed control strategies, the significant results were shown by herbicides and hand weeding. The resultsshown by hand weedingwere due to the completeelimination of weeds, whilethose by herbicides were due to their high selectivity and toxicity as compared to othertreatments. The pre-emergence application of herbicides was found effective in controlling both monocot and dicot weeds resulting in reduction of weed biomass (Patel et al., 2000). Similar results were also communicated by Khatam et al. (2013) in their studies on maize.

Plant height (cm)

The results revealed that the height of maize showed significant values regarding the weed control measures. The results presented in Table 2 revealed that the tallest maize plants were recorded in hand weeding plots (219.89 cm) followed by atrazine (219.08 cm) and S-metolachlor (218.67 cm). However it was statistically at par with the plant height recorded in different mulches i.e. black plastic (216.66 cm), wheat straw (215.58 cm) and saw dust (214.99 cm). Similarly the lowest plant height (206.96 cm) was observed in weedy check. The utmost maize plant height in hand weeding and herbicide treatments were due to availability of more nutrients to maize plants in the absence of weeds. Similarly the satisfactory results obtained by different mulches were due to the positive impact of mulches on the soil physical conditions, soil moisture retention and lowered soil temperature. These results are in accordance with the work of Mohammadi et al. (2005) who concluded that herbicidal treatment increased plant height. Herbicides were very effective in controlling weeds and offer sizeable increase in crop growth and productivity (Santos, 2009).

500 Kernel weight (g)

The data regarding 500 kernel weight is presented in the Table 2. The data revealed that the highest 500 kernel weight (160 g) was noticed in hand weeding plots which were statistically at par to atrazine (159.75 g). Similarly among various mulches the maximum 500 kernel weight (148 g) was noticed in black plastic mulch, whereas the lowest 500 kernel weight (105.75 g) was observed in weedy check plots. In general, the results demonstrated that both the herbicides and manual weeding effectively increased the kernel weight of maize. Similar observations were also recorded by Khan et al. (2012a) who stated that kernel weight was greater for the mechanical and chemical treatments than for control. The highest 500 kernel weight in hand

weeding and herbicides treated plots were due to less weed density, higher dry matter accumulation and higher resource partitioning towards grain as compared to other treatments. However, in weedy check plots, the low 500 kernel weight was due to improper nutrients availability and heavy weed infestation. Similar results have been reported by Khan et al. (2014).

Table 2 - The effect of different herbicides, plants extracts and mulches on plant height (cm) and 500 kernels weight (g) in maize

Treatment	Plant height (cm)	500 kernels weight (g)
S-metolachlor	218.67 a	156.75 ab
Pendimethaline	218.46 a	152.00 ab
Atrazine	219.08 a	159.75 a
Eucalyptus extract	210.92 b	126.75 e
Ammi visnaga extract	208.82 b	124.50 e
Black plastic mulch	216.66 a	148.00 bc
Wheat straw mulch	215.58 a	138.25 cd
Saw dust mulch	214.99 a	133.00 de
Hand weeding	219.89 a	160.00 a
Weedy check	206.96 b	105.75 f
LSD 0.05	4.4279	10.428
CV%	1.42	5.12

Number of kernels ear^{-1}

Perusal of data revealed that numbers of kernels cob^{-1} were significantly affected by different weed control measures (Table 3). The results demonstrated that the greatest number of kernels ear^{-1} (473.50) were obtained in hand weeding treatment followed by atrazine (466.50) while the lowest number of kernels ear^{-1} (389) were noticed in check plots. The overall results showed that both hand weeding and the herbicides positively affected the number of kernels ear^{-1}. The higher number of kernels ear^{-1} in hand weeding and herbicides treated plots were due to less weed competition, which made all the resources available to the maize crop. While the lower number of kernels ear^{-1} in weedy check plots were due to unchecked weeds infestation which drastically affected the plant growth and yield due to high competition for the available resources. The observations are in line with Khan et al. (2011) who also found that herbicides and hand weeding effectively control the weeds and positively enhanced the plant height and number of kernels ear^{-1}. Nadeem et al. (2010) also concluded that herbicides and hand weeding had a great impact on weeds control and yield parameters of maize crop.

Biological yield (kg ha^{-1})

The analysis of data demonstrated that biological yield (kg ha^{-1}) of maize was considerably affected by different weed control treatments (Table 3). The results showed that maximum biological yield (9000.6 kg ha^{-1}) was recorded in hand weeding plots, leaving behind herbicide practiced treatments i.e. atrazine and S-metolachlor (8616.8 and 8555.9 kg ha^{-1}), respectively (Table 3). The lowest biological yield (6268.5 kg ha^{-1}) was obtained in weedy check plots. Likewise among different mulching techniques, the highest (8059.8 kg ha^{-1}) biological yield was observed in black plastic mulch. These findings are in agreements with those reported by Schroetteret al. (2006) and Resendeet al. (2006). Galzinaet al. (2008) also observed that the shoot mass of maize plants was more in treated plots especially in herbicide applied plots as compared to check plots.

Table 3 - The effect of different herbicides, plants extracts and mulches on number of kernels ear^{-1} and biological yield (kg ha^{-1}) in maize

Treatment	Number of kernels ear^{-1}	Biological yield (kg ha^{-1})
S-metolachlor	464.50 ab	8555.9 ab
Pendimethaline	460.00 abc	8318.6 bc
Atrazine	466.50 ab	8616.8 ab
Eucalyptus extract	431.75 de	6969.1e
Ammi visnaga extract	427.50 e	6871.5 e
Black plastic mulch	452.75 bc	8059.8 cd
Wheat straw mulch	445.50 cd	7882.2 cd
Saw dust mulch	444.25 cde	7715.8 d
Hand weeding	473.50 a	9000.6 a
Weedy check	389.00 f	6268.5 f
LSD 0.05	16.871	480.83
CV%	2.61	4.23

Grain yield (kg ha^{-1})

Data regarding grain yield revealed that grain yield was notably affected by different treatments (Table 4). The highest grain yield (4992.5 kg ha^{-1}) was noticed in hand weeding plots, followed by herbicide atrazine and S-metolachlor treated plots (4636.4 and 4562.8 kg ha^{-1}) respectively, while among

different mulches the maximum grain yield (4054.4 kg ha^{-1}) was observed in black plastic mulch treatment (Table 4). These findings revealed that all the weed control techniques significantly affect the grain yield of maize crop. Furthermore the minimum grain yield (2469.9 kg ha^{-1}) was recorded in weedy check plots. The results in the present study are similar to the findings of Ali et al. (2011) who reported increase in grain yield of maize crop with the use of herbicides and mulch as the herbicide suppresses the germination of weeds providing a competition free environment for the crop plants. In another similar study Hassan et al. (2010) also reported herbicides as the most efficient method of weed control in maize. The low yield in weedy check might be due to weed competition with the maize crop. Similar results of low grain yield in weedy check have also been reported by Khan et al. (2016).

Table 4 - The effect of different herbicides, plants extracts and mulches on grain yield (kg ha^{-1}) and harvest index (%) in maize

Treatment	Number of kernels ear^{-1}	Biological yield (kg ha^{-1})
S-metolachlor	4562.8 b	53.33 abc
Pendimethaline	4202.5 c	50.52 bcd
Atrazine	4636.4 b	53.88 ab
Eucalyptus extract	3441.6 e	49.40 d
Ammi visnaga extract	3374.4 e	49.15 d
Black plastic mulch	4054.4 cd	50.37 cd
Wheat straw mulch	3938.4 cd	50.08 cd
Saw dust mulch	3883.8 d	50.38 cd
Hand weeding	4992.5 a	55.51 a
Weedy check	2469.9 f	39.36 e
LSD 0.05	290.43	3.4765
CV%	5.06	4.77

Harvest index (%)

The data demonstrated that weed control treatments had considerable effect on harvest index (Table 4). The upper limit harvest index (55.51%) was obtained in hand weeding plots leaving behind atrazine having harvest index of 53.88% whereas the lowest harvest index (39.36%) was calculated from weedy check plots. The results revealed that hand weeding and herbicides positively enhanced the harvest index which was due to the fact that these practices effectively control the weeds and increased the grain yield due to lower weed crop competition as compared to control. These conclusions are in close immediacy with the work of Saeed et al. (2010) who reported utmost harvest index (HI) in less weeds infected plots.

Conclusion can be drawn from the experiment that among all the weed control measures hand weeding and herbicides atrazine and S-metolachlor positively control the weeds and significantly increase the yield and yield components of maize. Hence it is recommended that hand weeding and herbicides i.e. atrazine and S-metolachlor should be used to control weeds and to achieve maximum grain yield in maize crop.

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