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Effect of Different Herbicides on Weeds, Growth and Yield of Spring Planted Maize (*Zea mays L.*)

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Abstract
A field experiment was conducted at, Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan during spring 2008 to study the effect of new pre-emergence herbicide Penthalin plus-35EC (Pendimethalin 20 % + prometryn 15 %) on weeds, growth and yield of spring planted maize (*Zea mays* L.). The experiment comprised eight treatments: weedy check, Penthalin plus-35EC @ 2000, 2500, 3000, 3500, and 4000 ml ha^{-1} (Pendimethalin + prometryn @ 700, 875, 1050, 1225 and 1400 g a.i ha^{-1}), Stomp-35EC @ 3000 ml ha^{-1} (Pendimethalin @ 1050 g a.i ha^{-1}) and manual hoeing. Main weeds were *Cyperus rotundus*, *Tribulus terrestris*, *Dactyloctenium aegyptium* and *Cyndon dactylon*. The results showed that the most effective treatment in controlling weed, reducing the dry matter of weed and increasing maize grain yield were manual hoeing, stomp 35-EC (Pendimethalin @ 1050 g a.i. ha^{-1}) and Penthalin plus-35EC (Pendimethalin + Prometryn @ 1225 g a.i. ha^{-1}), producing grain yield of 8.05, 7.92 and 7.671 t ha^{-1}, respectively as compared to 4.561 t ha^{-1} for untreated control plot. The study concludes that manual hoeing and stomp 35-EC can be more effective as compare to all other treatments with out compromising on maize grain yield loss due to weeds

Key Words: *Zea mays*, weeds, pendimethalin, pre-emergence.

Introduction: Maize (*Zea mays* L.) occupies third rank among the cereal crops after Wheat and Rice, extensively sown under irrigated and somewhat in rainfed areas of almost all the provinces of Pakistan but Punjab and NWFP are the major producers (GOP, 2008). In Pakistan, maize is grown on an area of 1,026 thousand hectares with the production of 3.313 million tones and average grain yield of 3264 kg ha^{-1} (GOP, 2008). But the average national yield per hectare is still far below as compare to the other maize growing countries of the world like Italy (9530 kg ha^{-1}), USA (8600 kg ha^{-1}), Canada (6630 kg ha^{-1}), Argentina (5650 kg ha^{-1}) and China (4570 Kg ha^{-1}) (Anonymous, 2005). Despite suitable production environment and high yielding varieties of maize, the yield per hectare in Pakistan is still very low. Considering factors responsible for low yield, weed infestation is of prime importance. Excessive growth of weeds in maize field leads to 66 % to 80 % reduction in crop yield (Adigun, 2001 and Ford and Pleasant, 1994). Weeds compete with the crop plants for space, light, moisture, nutrients and carbon dioxide, which reduced not only the yield, grain quality and hinder harvest operations but also increase the cost of production (Rutta *et al.* 1991).

To minimize the weeds losses several methods are available such as mechanical, cultural, biological and chemical control methods. Exhausted by cultural method, farmers are moving towards other alternative methods of weeds control. In this scenario, chemical weed control is the best option. Chemical control method is quick, more effective, time and labour saving method than others. Chemical weeds control method is suggested by many researchers (Johnson *et al*., 1997, Khan and Haq, 2004, Juhl, 2004 and Toloraya *et al*., 2001 etc.). Success of weeds control methods depends upon several factors; however the weed emergence pattern, application timing and stage of crop are important in chemical control (Hoverstad *et al.*, 2004). Similarly, time of application of herbicides is very important for proper controlling of weeds and the effectiveness of herbicides can be increased (Vandini et *al.*, 2005).

The present study was concluded to see the effect of new herbicide Penthalin plus-35EC (Pendimethalin 20 % + prometryn 15 %) and compare their efficiency with other commonly used herbicide stomp-35EC (Pendimethalin) in controlling weed and consequent effect on weeds and yield components of maize crop.

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Materials and Methods

Herbicidal efficacy was tested through the application of pre-emergence herbicides in comparison with standard herbicide, hand weeding and weedy check in maize crop during spring 2008 at Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan. The experiment was laid out in randomized complete block design having net plot size 5 × 3 m with three replications. Maize hybrid "Double Top Cross (DTC)" was sown on 8th February, 2008 using recommended seed rate of 25 kg ha^{-1} maintaining row to row distance of 75 cm. Plant to plant distance of 20 cm was achieved by thinning out the extra plants at early growth stage. The fertilizer @ 150 kg nitrogen + 100 kg phosphorous (P_2O_5) ha^{-1} was applied in the form of urea and Diamonium phosphate (DAP), respectively. Whole quantity of the phosphorus and half of the nitrogen was broadcasted and incorporated into the soil at the time of sowing while remaining half of the nitrogen was top dressed at the time of 2nd irrigation. The herbicides were applied just after sowing of maize crop by "Knapsack" hand sprayer with flat fan nozzle. The volume of spray was determined, using the standard calibration method. Hoeing was done twice with hand hoe in manual hoeing treatments when the soil was in proper field capacity condition after 1st and 2nd irrigation. All other agronomic practices were kept normal and uniform for all treatments.

Table 1. Detail of herbicidal treatments in the experiment.

Treatments	Common name	Application time	Dose g a. i. ha^{-1}
W_0: Weedy check			control
W1:Penthalin plus 35-EC	Pendimethalin 20 % + Prometryn 15 %	Pre-emergence	700
W_2: Penthalin plus 35-EC	Pendimethalin 20 % + Prometryn 15 %	Pre-emergence	875
W_3: Penthalin plus 35-EC	Pendimethalin 20 % + Prometryn 15 %	Pre- emergence	1050
W_4: Penthalin plus 35-EC	Pendimethalin 20 % + Prometryn 15 %	Pre-emergence	1225
W5:Penthalin plus 35-EC	Pendimethalin 20 % + Prometryn 15 %	Pre-emergence	1400
W6: Stomp 35-EC	Pendimethalin	Pre-emergence	1050
W_7: Manual hoeing			Two hoeing

The data were recorded on weed density m^{-2}, plant height (cm), number of grain rows per cob, number of grains per cob, 1000-grain weight (g) and grain yield (t ha^{-1}) and analyzed statically by using Fisher's analysis of variance technique and least significant difference (LSD) test at 5 % probability level to compare significant treatment means (Steel *et al*., 1997).

Results and Discussion

A. Weeds

Weeds density (m^{-2}) 20 days after spray

Cyperus rotundus (Deela), *Tribulus terrestris* (Bakhra), *Dactyloctenium aegyptium* (Madhana grass), *Cyndon dactylon* (Khabal grass), *Fumaria indica* (Shahtara), *Chenopodium album* (Bathu), *Convolvulus arvensis* (lehli), *Rumex dentatus* (Jangli Palak) and *Portulaca oleracea* (Kulfa) were present in the field however, *Cyperus rotundus* (Deela) and *Tribulus terrestris* (Bakhra) were the dominant weeds.

Cyperus rotundus

The data regarding to *C. rotundus* revealed that weed denstiy at 20 days after sowing (DAS) was significantly affected by all weed control treatmetnt (Table 1) compared to weedy check. The maximum reduction of *C. rotundus* (90.95%) was recorded in treatment where manual hoeing (W_7) was done and it was followed by treatment W_5 where Pendimethalin + Prometryn @ 1400 g a.i. ha^{-1} was applied (80.41% reduction over control) which was statistically at par with W_6 treatment (Pendimethalin

@ 1050 g a.i. ha^{-1}) which reduced (76.55 %) the weed density over control. The main possible reason of variation in weed density of C. *rotundus* over weedy check could be attributed to the mortality of weeds due to chemical and mechanical injury in the form of manual hoeing and different herbicide treatments. These results about the difference in the efficiency of various weed control practices are supported by Bogdan *et al.* (2002) and Janjic *et al.* (2004).

Tribulus terrestris

The data regarding to *T. terrestris* (20 days after spray) revealed that density of *T. terrestris* significantly controlled by all the weed control treatments over the weedy check (W_0). The statistically maximum reduction (82.16 %) in the density of *T. terrestris* was observed in manual hoeing (W_7) and was statistically at par with Pendimethalin @ 1050 g a.i. ha^{-1} (W_6) (78.25 %) and Pendimethalin + Prometryn @ 1400 g a.i. ha^{-1} (69.57 %) in W_5 treatment. The minimum density of *T. terrestris* was recorded in weedy check plots (W_0) where density of the weeds were 7.667 m^{-2} and it was followed by Pendimethalin + Prometryn @ 700 g a.i. ha^{-1} (23.92 %) in W_1 treatment. The maximum density of the weeds was in the weedy check plots due to undisturbed growth of the weeds. Mortality of *T. terrestris* was different among the various herbicidal treatment due to difference in their mode of action might be the main reason for significantly different control over the density of *T. terrestris* The lowest density of *T. terrestris* (in manual hoeing) could be attributed to more mortality due to up rooting and mechanical injury of *T. terrestris.* The results of weed control were strongly supported by Djurkic *et al*. (1997) and Vanbiljon *et al.* (2007).

Total weed density

Total weed density 20 days after spray given in Table 2 revealed that all the weed control treatments significantly controlled the all weed density compared to weedy check (W5). Maximum weed control (90.68 %) was recorded where manual hoeing was done and it was statistically at par with Pendimethalin + Prometryn @ 1400 g a.i. ha^{-1} (W_5), S-metolachlor at 1920 g a.i. ha^{-1} (76.13%) which gave 78.75 % weed control and it was statistically at par with Pendimethalin @ 1050 g a.i. ha^{-1} (W_6) which reduced weed density 74.82 %. The lower weed density due to manual hoeing and herbicide application over weedy check might have been due to the mortality of weeds in these treatments while the maximum weed density was found in weedy check due to unchecked weed growth as no weed control practices were applied. These results are supported by those of Xu-peiguo (2004).

Table 2. Density of *Cyperus rotundus, Tribulus terrestris* and total weed density at 20 DAS as influenced by various weed control treatments.

Treatments	**Density of *C. rotundus***	**Density of *T.terrestris***	**Total weed density**
W_0: weedy check	112.3 a	7.667 a	152.2 a
W1: Pendimethalin + Prometryn @ 700 g a.i ha^{-1}	88.67 b	5.833 b	123.7 b
W_2: Pendimethalin + Prometryn @ 875 g a.i ha^{-1}	65.83 c	4.667 c	109.2 c
W_3: Pendimethalin + Prometryn @ 1050 g a.i ha^{-1}	48.50 d	3.500 d	82.83 d
W_4: Pendimethalin + Prometryn @ 1225 g a.i ha^{-1}	31.50 e	2.667 de	48.00 e
W5: Pendimethalin + Prometryn @ 1400 g a.i ha^{-1}	22.00 f	2.333 def	32.33 f
W6: Pendimethalin 1050 g a.i ha^{-1}	26.33 f	1.667 ef	38.33 f
W_7: Manual hoeing	10.67 g	1.333 f	14.17 g

Weed Density 40 Days after Spray (m^{-2})

Cyperus rotundus

Observation regarding to *C. rotundus* density 40 days after spray presented in the Table: 3 showed that all the weed control treatments significantly controlled *C. rotundus* density compared to weedy check (W_0). The significantly minimum density of *C. rotundus* (13.17 m^{-2}) was recorded in manual hoeing treatment which gave the 90.03 % of weed control in W_7 treatment over weedy check plots and it was followed by W_5 treatment (68.45 %) where Pendimethalin + Prometryn @ 1400 g a.i. ha^{-1} was applied which was statistically at par with (W_6) Pendimethalin @ 1050 g a.i. ha^{-1} which reduced the weed density 74.15 %. The minimum control of weed density of *C.* rotundus was recorded in weedy check plots (132.2 m^{-2}) (W_0) which was followed by Pendimethalin + Prometryn @ 700 g a.i. ha^{-1} (22.69 %) in W_1 treatment. The possible reason of lower weed density could be the mortality of weeds due to chemical and mechanical injury by manual hoeing and different herbicides treatments. The minimum weed density of C. *rotundus* in herbicidal treatment (Pendimethalin + Prometryn @ 1400 g a.i. ha^{-1}) might have been due to inhibitory action of herbicide on the germination of C. *rotundus* seed. Similar results about that all weed control practices decreased the weed density over weedy check have been reported by Arnold *et al.* (2005) and James *et al*. (2006).

Density of *T. terrestris*

Data taken of *T. terrestris* density 40 days after spray given in Table: 3 revealed that all weed control treatments again significantly controlled *T. terrestris* density compare to weedy check (W_0). Comparison of individual treatments means showed that the statistically maximum weed density of *T. terrestris* (7.667 m^{-2}) was recorded in the weedy check (W_0) plots and it was followed by Pendimethalin + Prometryn @ 700 g a.i. ha^{-1} (23.92 % control in W_1 treatment).. The maximum control of *T. terrestris* (82.61 %) was recorded in treatment W_7 where manual hoeing (1.333 m^{-2}) was done which was statistically at par with Pendimethalin @ 1050 g a.i. ha^{-1} (W_6) and Pendimethalin + Prometryn @ 1400 g a.i. ha^{-1} which gave the 78.25 % and 72.56 % control over weed. The lower weed density over weedy check might have been due to the mortality of weeds due to chemical and non-chemical injury by manual hoeing and different herbicides treatments. Among the herbicidal treatments, difference over the control on weeds could be due to the difference in doses and their inhibitory action of herbicides. These results are supported by Manhadi *et al*. (2007) and Soukup *et al*. (2008) who reported the maximum control in the treated plots.

Total weed density

The data regarding weed density in spring planted maize (*Zea mays* L.) revealed total weed density (40 days) after spray was significantly affected by all the weed control treatments shown in the Table: 4.2.3. The statistically maximum (169.3 m^{-2}) total weed density was recorded in weedy check (W_0 treatment) where no weed control practices were done and it was followed by Pendimethalin + Prometryn @ 700 g a.i. ha^{-1} (16.00 %) (W_1). The maximum reduction in the weeds density (W_7) (88.97 %) was recorded where manual hoeing was done (18.67 m^{-2}) and was followed by W_5 treatment where Pendimethalin + Prometryn @ 1400 g a.i. ha^{-1} was applied which reduced the weeds density up to 70.36 %. The mortality of weed density in manual hoeing could be attributed due to uprooting and mechanical injury of weeds and the variation of weeds in the chemically treated plots might have been difference in the mode of action of herbicides which significantly controlled over the weeds in all the chemically control treatments. These results are in line with those reported by Roy *et al* (2002), Skoko and Zivanovic (2002). They reported that there has been significant difference in weed density of various weed control practices and negatively affected the weed growth**.**

Table 3. Density of *Cyperus rotundus*, *Tribulus terrestris* and total weed density at 40 DAS as influenced by various weed control treatments.

Treatments	**Density of *C. rotundus***	**Density of *T.terrestris***	Total weed density
W_0: weedy check	132.2 a	7.667 a	169.3 a
W1: Pendimethalin + Prometryn @ 700 g a.i ha^{-1}	102.2 b	5.833 b	142.2 b
W_2: Pendimethalin + Prometryn @ 875 g a.i ha^{-1}	79.50 c	4.667 c	121.2 c
W_3: Pendimethalin + Prometryn @ 1050 g a.i ha^{-1}	59.50 d	3.500 d	95.83 d
W_4: Pendimethalin + Prometryn @ 1225 g a.i ha^{-1}	36.17 e	2.667 de	62.17 e
W5: Pendimethalin + Prometryn @ 1400 g a.i ha^{-1}	28.00 f	2.333 def	50.17 f
W6: Pendimethalin 1050 g a.i ha^{-1}	34.17 f	1.667 ef	54.83 f
W_7: Manual hoeing	132.2 a	1.333 f	18.67 g

B. Maize (Zea mays L.)

Plant height at harvest (cm)

Plant height reflects efficiency of the plant for photosynthetic radiation interception and vegetative growth character of crop plants in response of various applied inputs. Data regarding to plant height was given in Table: 4 represented that plant height was significantly affected by various weed control practices. The maximum plant height (198.9 cm) was recorded with manual hoeing (W_7) which was statistically at par with Pendimethalin @ 1050 g a.i. ha^{-1} (198.4 cm) in W_6 treatment, followed by Pendimethalin + Prometryn @ 1225 g a.i. ha^{-1} (W_4) (185.7 cm). The significantly minimum plant height

(164.0 cm) was recorded in weedy check (W_0) which was statistically at par with Pendimethalin + Prometryn @ 1400 g a.i. ha^{-1} (166.4 cm). The Variation in plant height of maize in all weed control treatments could be attributed to varying effect of weed competition duration for available resources offered by different weed densities in different weed control practices. These results are in line with Akhtar *et al*. (1998) and Hussain *et al*. (1998), who stated maximum plant height was in control plots.

Number of grain rows per cob

Number of grain rows per cob directly affects cob weight and ultimately grain yield of maize. The results indicated that maximum number of grain rows per cob (38.69) in manual hoeing (W_7) and were statistically at par with Pendimethalin @ 1050 g a.i. ha^{-1} (38.23) in W_6. The statistically minimum number of grain rows per cob (35.44) was recorded in weedy check plots (W_0) and was followed by Pendimethalin + Prometryn @ 700 g a.i. ha^{-1} (35.93) in W_1 treatment. The observations of this parameter showed that good weed control practices are effective to get more number of grain rows per cob and consequently higher grain yield. These results are in close agreement with the results obtained by Singh *et al.* (1985) and Sulewska *et al.* (2006), Who reported that weed controlled practices resulted in increased number of grain rows per cob.

Total number of grains per cob

The total number of grains per cob is an important yield component parameter of maize. The data in Table: 4 indicated that all weed control practices significantly affected the total number grains per cob. The maximum number of grains per cob (559.6 grain per cob in W_7 treatment) in manual hoeing and it was statistically at par with (W_6) treatment where Pendimethalin @ 1050 g a.i. ha^{-1} (570.6 grains per cob) was applied and with Pendimethalin + Prometryn @ 1225 g a.i. ha^{-1} (565.7 grains per cob in W_5). The statistically minimum number of grains per cob (429.7) was recorded in weedy check (W_0) and it was followed by Pendimethalin + Prometryn @ 700 g a.i. ha^{-1} (468.8 grains per cob in W_1 treatment). The highest number of grains per cob in manual hoeing was because of very less number of weeds and consequently more photosynthates are available for plant growth and development. These results are confirmatory to Tanveer *et al*. (1999). They concluded that all weeds control treatments significantly increase the number of grain rows and number of grains per cob.

Table 4 Efficacy of different herbicides on yield components of maize

Treatments	Plant height (cm)	Number of grain rows / cob	Number of grains / cob	Cob length cm	1000-grain weight (g)	Grain yield (t ha^{-1})
W_0: weedy check	164.0 e	35.44 d	429.7 d	15.25 d	252.5 d	4.516 d
W1: Pendimethalin + Prometryn @ 700 g a.i ha^{-1}	175.1 cd	35.93 d	468.8 d	15.88 d	320.3 c	4.861 d
W_2: Pendimethalin + Prometryn @ 875 g a.i ha^{-1}	173.4 bc	36.97 b	520 bc	16.98 c	337.2 b	6.743 b
W_3: Pendimethalin + Prometryn @ 1050 g a.i ha^{-1}	172.0 bc	36.60 b	534.7 b	16.93 c	346.1 b	7.019 b
W_4: Pendimethalin + Prometryn @ 1225 g a.i ha^{-1}	185.7 b	38.11 a	559.6 a	17.96 b	520.1 a	7.671 a
W5: Pendimethalin + Prometryn @ 1400 g a.i ha^{-1}	166.4 de	36.35 c	506.9 c	16.64 c	306.3 c	6.325 c
W6: Pendimethalin 1050 g a.i ha^{-1}	198.4 a	38.23 a	565.7 a	18.01 b	527.6 a	7.920 a
W_7: Manual hoeing	198.9 a	38.69 a	570.6 a	18.76 a	540.4 a	8.051 a

Cob length (cm)

Cob length is also very important yield determining factor of maize crop. Longer the cob length, more would be number of grains per cob and consequently higher yield in the form of grains. The data regarding to this parameter is given in the Table 4 revealed that all weeds control treatments significantly affected the cob length than weedy check. The data indicated that maximum cob length (18.76 cm) was obtained in manual hoeing (W_7) than all other weed control treatments which was followed by Pendimethalin @ 1050 g a.i. ha^{-1} (18.01 cm in W_6 treatment). The significantly minimum cob length (15.25 cm) was recorded in weedy check plot (W_0). The cob length was highly significantly in manual hoeing, Pendimethalin and Pendimethalin + Prometryn was mainly due to timely and efficiently weed control of weeds and thus, less weed competition period in these treatments which allowed the maize plant to produce more photosynthetic material by using available nutrients. These results are confirmatory with those of Singh and Singh (2003) and Stefanovic *et al*. (2004). They founded that greater cob length in weed control treatments and smallest cob length in weedy check plots.

1000-grain weight (g)

Apart from combined effect of all the other individual yield determining factors, the ultimate final grains yield of a cereal crop depends upon the 1000-grain weight and seed development nourished under applied inputs and various weed control treatments. Any variation in the 1000-grain yield will affect the grain yield. The maximum 1000-grains weight (540.4 g) was attained with manual hoeing (W_7) which was statistically at par with Pendimethalin @ 1050 g a.i. ha^{-1} (W_6) (527.6 g) and Pendimethalin + Prometryn @ 1225 g a.i. ha^{-1} (W_5) (520.1 g). It was followed by Pendimethalin + Prometryn @ 875 g a.i. ha^{-1} (W_3) (346.1 g) which is statistically at par with Pendimethalin + Prometryn @ 1050 g a.i. ha^{-1} (W_2) (337.2 g). The significantly minimum 1000-grains weight (306.3 g) was founded in weedy check plots (W_0) and was followed by Pendimethalin + Prometryn @ 1400 g a.i. ha^{-1} (252.5 g). The significant variation for 1000-grain weight in weed control treatments than weedy check was due to vigorous growth and development of maize plants, which resulted in more photosynthates assimilation in grains thus more 1000-grains weight. These results are inline with those of Tanveer *et al*. (1999), Hussain *et al*. (1998) and Baye and Bouchache (2007), who concluded that 1000-grain weight was greater in various controlled treatments than in weedy check in maize.

Grain yield (tha^{-1})

Grain yield is a function of the cumulative behavior among various yield determining components namely the number of cobs per plants, cob length, number grains per cob and 1000-grain weight which showed variations by prevailing growing conditions and various crop management practices. The significantly maximum grain yield (78.28 % grains increased over check) (8.071 t ha^{-1}) with manual hoeing in W_7 treatments which was statistically at par with W_6 and W_4 treatments where Pendimethalin @ 1050 g a.i. ha^{-1} (75.37 %) and Pendimethalin + Prometryn @ 1225 g a.i. ha^{-1} (69.86 %) was applied. The statistically minimum grain yield was obtained in weedy check plots (4.516 t ha^{-1}) and was followed by Pendimethalin + Prometryn @ 700 g a.i. ha^{-1} (29.89 % reduced grains yield over weedy check). The variation in grain yield as compare to weedy check plots was different in all weed controlled treatments and ranged from 29 % to 78 %. This was mainly because of more number of grain rows per cob, number of grains per cob and 1000-grain weight over weedy check. The lowest grain yield was recorded in weedy check could be attributed to maximum weed density which suppressed the growth and development of maize plants by competing for moisture, light and nutrients. The efficiency of various chemicals and other weed control practices in enhancing grain yield had also been observed by Toloraya *et al*. (2001) and Stefanovic *et al*. (2004).

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