WEEDS PERFORMANCE IN MAIZE CROP AGAINST DIFFERENT TILLAGE AND WEED MANAGEMENT PRACTICES

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ABSTRACT

An experiment to study the performance of weeds in maize crop against different tillage and weed control methods was conducted at Agronomy Research Farm, The University of Agriculture Peshawar during summer 2016. Field experiment was conducted in randomized complete block design (RCBD) with split plot arrangement having four replications. Tillage practices i.e. chisel plough + rotavator, mouldboard plough + rotavator, cultivator + rotavator and rotavator were assigned to main plots. Weeds management practices include control, hoeing 15 days after sowing, hoeing 15 and 30 days after sowing, hoeing 15, 30 and 45 days after sowing, and herbicide (Nicosulfuron) were kept in subplots. The results revealed that chisel plough + rotavator significantly reduced weeds m^{-2} (122, 101 and 125 weeds m^{-2}), weeds fresh weight (19.73 g m^{-2}, 116.35 g m^{-2} and 252.56 g m^{-2}) and weeds dry weight (6.83 g m^{-2}, 38.69 g m^{-2} and 80.61 g m^{-2}) at 30, 45 and 60 days after sowing, respectively. The operation of chisel plough + rotavator produced tallest plants (221.22 cm) with maximum grain rows ear^{-1} (16) and shelling percentage (78.14%). Among weed control methods, hoeing 15, 30 and 45 days after sowing showed maximum plant height (226.41 cm), grain rows ear^{-1} (16), and shelling percentage (79.11%). All weed control methods showed significant reduction in weeds m^{-2}, weeds fresh weight and weeds dry weight. Interaction was also found significant for weeds m^{-2} at 60 DAS. Lowest weeds (56 weeds m^{-2}) at 60 DAS was recorded when seedbed was prepared with chisel plough + rotavator with 3 hoeings (hoeing 15, 30 and 45 days after sowing). It can be concluded that treatment of chisel plough + rotavator for seedbed preparation and doing manual hoeing at 15, 30 and 45 days after sowing maize significantly reduced weeds density and growth in maize crop.

Keywords: Tillage, Rotavator, Weeds management, Hoeing, Weeds dry matter, *Zea mays.*

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INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal crop in the world. In Pakistan, maize is the fourth largest grown crop after wheat, cotton and rice. In the year 2015, maize was grown in Pakistan on an area of 1.143 million hectares which produced 4.937 million ton grains with national average yield of 4321 kg ha^{-1}. In Khyber Pakhtunkhwa province, it was cultivated on 463 thousand hectares with a total production of 909.7 thousand tones with an average grain yield of 1965 kg ha^{-1} (MNFSR, 2015). Proper tillage practices and weed control at proper time are the key problems for attaining the highest grain yield of maize in Pakistan. Appropriate tillage practices reduce degradation of soil health and maintain crop productivity as well as conserve soil ecosystem (Abbas *et al*., 2017). Tillage is one of the most essential components of crop production system which influences weed growth. Secondary tillage ensures preparation of a fine seedbed (Ghimire *et al*., 2016). Deep tillage effectively controls weed infestation due to which more moisture and nutrients availability is ensured for crop growth which ultimately increases crop yield (Mushtaq *et al*., 2015). Tillage operations in maize crop facilitate germination of seed and promote plant growth and development.

Weed management is a significant factor for achieving highest maize productivity and to reduce yield losses in maize as a result of the poor weed management strategies practiced by maize farmers (Quee *et al*., 2018). Weed invasion contributes 18 to 35% loss in economic yield of the crop (Anonymous, 2016), while in severe circumstances the complete failure of crop has been reported (Patel *et al*., 2016). Weed infestation negatively affects the quality and quantity of grain production due to their interference with main crop by sharing nutrients, water and space with crop which ultimately result in economic losses (Chauhan *et al*., 2012). Control of weeds is one of the utmost important elements for sustainable agriculture (Arif *et al*., 2013). Extreme weeds growth in maize field may lead to 66 - 80% reduction in crop yield (Adigun, 2001). Weeds compete for space, water, light and nutrients with main crop and thereby decrease crop yield by 50% and increase production cost (Chikoye *et al*., 2001; Shah *et al*., 2003). Chemical weed control method is quick, more effective, and labour saving than other methods. The pattern of weeds emergence, weeds stage and herbicide application timing are important in effective control of weeds through chemicals (Hoverstad *et al*., 2004).

One of the major problems in maize field is the presence of weeds that competes with maize for resources like water, nutrients, light and other necessary requirements (Roshdy *et al.,* 2017). Ali et al. (2003) reported that herbicides application significantly decreased the weed density in maize crop. Weeds cause a reduction in maize yield up to 40% worldwide (Oerke and Dehne, 2004). Maize is most vulnerable to weeds competition especially at an early stage of its growth (Rajeshkumar *et al.,* 2017). Kolage et al. (2004) reported that manual weeding done at 3 and 5 weeks after sowing significantly reduced weed density. Sinha et al. (2003) claimed that efficiency of weed control was 91.9% when controlled with hand. Tillage operations greatly affect the composition of weeds communities (Ali *et al.,* 2011). Long term studies indicated that weed population and performance can be significantly minimized by adopting proper weed management practices (Kumar *et al.,* 2017). For achieving potential yield in maize production, weed management is considered as an important factor. Tillage is considered a major component in weed controlling program (Arif *et al.,* 2007). Although herbicides have proved to be quick, efficient and easy way to control weeds but on the other hand it is a potential threat for environment too (Felton and McCloy, 1992).

Keeping in view the losses due to weeds infestation with improper ploughing of soil before sowing, the present study was initiated with the aim to investigate the appropriate tillage practice(s) for seedbeed preparation along with the suitable weed control method(s) to minimize weeds population and performance to reduce its interference with crop growth under climatic conditions of Peshawar, Pakistan.

MATERIALS AND METHODS

To study the effect of tillage practices and weed control methods on weeds performance, an experiment was conducted at Agronomy Research Farm, the University of Agriculture Peshawar, Pakistan during summer 2016. The experimental farm is located about 1600 km north of the Arabian Sea and has continental type of climate. The research farm is irrigated by Warsak canal from river Kabul. Soil is clay loam, low in organic matter (0.88%), alkaline (pH 8.3) and calcareous ($CaCO3>3\%$) in nature (Liaqat *et al*., 2018). The experiment was laid out in randomized complete block design with split plot arrangement having four replications. Tillage practices viz., Chisel plough + rotavator, Mouldboard plough + rotavator, Cultivator + rotavator and Rotavator alone were assigned to main plots. Weed management practices including control, Hoeing 15 days after sowing, Hoeing 15 and 30 days after sowing, Hoeing 15, 30 and 45 days after sowing, and Herbicide (Nicosulfuron @ 70 g a.i. ha^{-1} as post emergence) were assigned to subplots. Azam variety of maize was sown with a seed rate of 30 kg ha^{-1}. Row to row distance was kept 75 cm and plant to plant 20 cm. Each sub plot size was 3m x 3.75m (5 rows per each subplot). Recommended dose of nitrogen and phosphorous was applied at the rate of 150 and 90 kg ha^{-1} respectively. All phosphorous and half of the nitrogen was applied at sowing time and the remaining half nitrogen was applied at 40 days after sowing. Herbicide (Nicosulfuron) was applied for the broad spectrum control of both grassy weeds and broad leaf weeds. Herbicide was sprayed at 4-5 leaf stage of weeds (25 days after sowing of maize). Irrigations were given according to crop water requirement and weather conditions (rainfall). Weather data (temperature and rainfall) of the experimental site for the crop growth season is shown in Figure 1.

Procedure for recording data

Weeds m^{-2} at 30, 45 and 60 days after sowing (DAS) were determined, respectively. A 25cm x 25cm iron ring was randomly thrown at three different places in each subplot. Number of weeds inside the ring were counted and converted into weed m^{-2}. For weeds fresh weight, the weeds were counted at 30, 45 and 60 DAS, cut and weighed to determine weeds fresh weight. The data recorded were converted into weeds fresh weight (g m^{-2}). The fresh weeds were then sun dried to a constant weight and weighed to find out weeds dry weight at 30, 45 and 60 DAS. The data were subsequently converted into weeds dry weight (g m^{-2}). Plant height (cm) was measured at physiological maturity stage by measuring height of five randomly selected plants in each sub plot from the base to the tip of plant including tassel with the help of meter rod. Their mean was calculated for a single reading. After harvesting ten ears were randomly selected from each experimental unit. Number of grain rows in these ears were counted and their average was determined. For grains ear^{-1} data, ten ears were taken randomly from each experimental unit. Grains in these ears were counted manually and averaged for a single data.

Statistical analysis

The recorded data were statistically analyzed according to analysis of variance technique used for randomized complete block design with a split plot arrangement. Least significant difference test ($P \leq 0.05$) was applied in case of significant F-test for mean comparison through the procedure described by Jan *et al*. (2009).

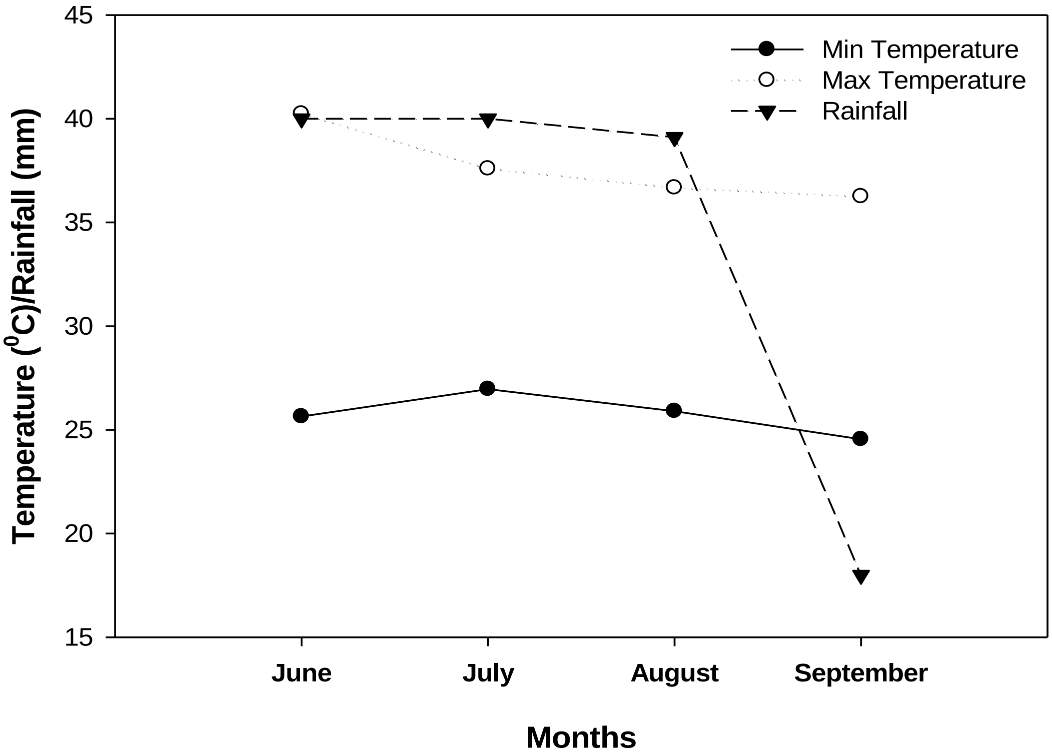


Figure 1. Total rainfall (mm) and mean maximum and minimum temperatures (^{O}C) for crop growth period (June-September 2016) in Peshawar (Pakistan Meteorological Department).

RESULTS AND DISCUSSION

Weeds m^{-2} at 30 days after sowing (DAS)

The data in Table-1 exhibit that weeds m^{-2} at 30 days after sowing (DAS) in maize were significantly ($P \leq 0.05$) affected by tillage practices and weed control methods. However, the interaction of tillage practices and weed control methods was non-significant ($P > 0.05$). Minimum weeds m^{-2} (122 weeds m^{-2}) at 30 DAS were recorded from chisel plough + rotavator followed by (146 weeds m^{-2}) from the mouldboard plough + rotavator. Maximum weeds m^{-2} (197 weeds m^{-2}) at 30 DAS were recorded from the rotavator alone. Lesser weed density due to operation of chisel plough might be attributed to the fact that maximum weeds were uprooted and buried by deep tillage of chisel plough. Similarly, rotavator chopped the uprooted weeds into small pieces which served as an organic matter for the existing crop. Khan *et al*. (2017) and Demjanova *et al*. (2009) reported that ploughing field with chisel plough showed minimum weeds population. Among weeds control methods, hoeing 15 days after sowing (DAS) showed lesser number of weeds m^{-2} (133 weeds m^{-2}) at 30 DAS as compared to control plots (185 weeds m^{-2}). Sampaio *et al*. (2015) and Ali *et al*. (2014) reported that hoeing resulted in lowest weeds growth in maize field with lowest population.

Weeds fresh weight (g m^{-2}) at 30 days after sowing (DAS)

Weeds fresh weight (g m^{-2}) at 30 days after sowing (DAS) was significantly affected by different tillage operations as well as weeds control methods (Table-1). Whereas, the interaction of tillage operations and weed control methods was non-significant statistically. Lowest weeds fresh weight (19.73 g m^{-2}) at 30 DAS was observed from treatment of chisel plough + rotavator followed by weeds fresh weight (24.99 g m^{-2}) from treatment of mouldboard plough + rotavator. Treatment of cultivator + rotavator produced fresh weeds biomass of 29.28 g m^{-2}. Highest weeds fresh weight (33.73 g m^{-2}) at 30 DAS was recorded from treatment of rotavator. The highest weeds fresh weight as recorded from treatment of rotavator proved that rotavator alone was least effective in weed control. Khan *et al*. (2017) reported maximum weeds fresh weight in plots tilled with rotavator alone. Chisel plough on the other hand cultivates the soil at a greater depth thus uprooting all weeds from soil, resulting in lowest weed density and ultimately lowest fresh weeds biomass. Gul *et al*. (2011) also reported significantly minimum weeds fresh weight with deep tillage operations. Among weed control methods, hoeing 15 days after sowing produced significantly lowest fresh weight of weeds (21.72 g m^{-2}) at 30 DAS as compared to control which produced maximum weeds fresh weight (32.15 g m^{-2}). Minimum weeds fresh weight was recorded from treatment of hoeing at 15 days after sowing (DAS) which might be due to the fact that hoeing practices resulted in lowest weeds population. Ali *et al*. (2015) revealed that various weed control methods such as hoeing significantly reduced weeds fresh weight.

Weeds dry weight (g m^{-2}) at 30 days after sowing (DAS)

The data in Table-1 reveal weeds dry weight (g m^{-2}) at 30 days after sowing (DAS) in maize crop as affected by various tillage operations and weed control methods. Mean values of the data showed significant effect ($P \leq 0.05$) of tillage practices and weeds control methods on weeds dry weight at 30 DAS. The chisel plough + rotavator showed minimum dry weight of weeds (6.83 g m^{-2}) at 30 days after sowing (DAS) followed by mouldboard plough + rotavator with weeds dry weight of 9 g m^{-2}. The use of rotavator alone produced maximum weeds dry weight (12.64 g m^{-2}) at 30 days after sowing (DAS). The lowest dry weight of weeds may be due to the fact that chisel plough cultivated the soil at a greater depth and uprooted the weeds successfully. Khan *et al*. (2017) reported lowest weeds dry weight in chisel plough tilled plots. Marwat *et al*. (2007) communicated that deep tillage suppressed weed growth and reduced weeds dry weight. Minimum weeds dry weight (7.71 g m^{-2}) at 30 days after sowing was observed from treatment of hoeing at 15 days after sowing. This is because the practice of hoeing efficiently controlled weeds which showed lowest weeds dry weight. Ali *et al*. (2014) and Khatam *et al*. (2013) reported significantly reduced weeds dry weight from the practice of hoeing. Maximum weeds dry weight (11.80 g m^{-2}) was recorded from the control.

Table-1. Weeds m^{-2}, weeds fresh weight (g m^{-2}) and weeds dry weight (g m^{-2}) at 30 DAS in maize crop as affected by different tillage practices and weeds control methods.

Tillage practices	Weeds m^{-2} at 30 DAS	Weeds fresh weight (g m^{-2}) at 30 DAS	Weeds dry weight (g m^{-2}) at 30 DAS
Chisel plough + Rotavator	122 d	19.73 d	6.83 c
Mouldboard plough + Rotavator	146 c	24.99 c	9.00 b
Cultivator + Rotavator	171 b	29.28 b	10.56 b
Rotavator	197 a	33.73 a	12.64 a
Weeds control methods			

Control	185 a	32.15 a	11.80 a
Hoeing 15 DAS	133 b	21.72 b	7.71 b
$LSD_{(0.05)}$ for TP	23	3.92	1.73
$LSD_{(0.05)}$ for WCM	10	1.88	1
TP x WCM	NS	NS	NS

Means of same categories followed by different letters are statistically different at 5% level of probability.
DAS = Days after sowing TP = Tillage practices WCM = Weed control methods
NS = non-significant

Number of Weeds m^{-2} at 45 days after sowing (DAS)

Table 2 exhibits data regarding number of weeds m^{-2} at 45days after sowing (DAS) in response to different tillage practices and weed control methods. Statistical analysis of the data revealed that tillage practices and weed control methods significantly affected (P≤0.05) number of weeds m^{-2}. Interaction of tillage practices and weed control methods for number of weeds m^{-2} at 45 days after sowing (DAS) was non-significant. Minimum number of weeds m^{-2} (101 weeds m^{-2}) at 45 days after sowing (DAS) was recorded from chisel plough + rotavator followed by mouldboard plough + rotavator (127 weeds m^{-2}). The maximum number of weeds (182 weeds m^{-2}) at 45 days after sowing were recorded from rotavator alone. Chisel plough when followed by rotavator effectively eliminated weed plants. Khan *et al*. (2017) revealed that chisel plough significantly decreased weeds m^{-2}. Knezevic *et al*. (2008) reported lesser number of weeds in deep tillage. Among the weed control methods, application of herbicide Nicosulfuron has drastically reduced weeds density (82 weeds m^{-2}) at 45 days after sowing as compared to hoeing practices. Highest weeds m^{-2} (206 weeds m^{-2}) at 45 days after sowing was recorded from control plots. The higher weeds density in weedy check plots may be attributed to the open soil surface and niches available to weeds for free and aggressive growth. The application of herbicide efficiently suppressed weeds between the rows as well as within the rows while hoeing practices could control weeds only between the rows. Tesfay *et al*. (2014) and Tahir *et al*. (2009) concluded that application of different herbicides significantly reduced weeds population including both grassy and broad-leaf weeds in maize crop.

Weeds fresh weight (g m^{-2}) at 45 days after sowing (DAS)

Table-2 shows fresh weight of weeds (g m^{-2}) at 45 days after sowing (DAS) which was significantly affected by different tillage operations and weed control methods. The interaction of tillage practices and weed control methods was non-significant. Highest fresh weight of weeds (198.90 g m^{-2}) at 45 days after sowing was recorded from the treatment of rotavator followed by weeds fresh weight (180.36 g m^{-2}) at 45 days after sowing from treatment of cultivator + rotavator and weeds fresh weight (142.68 g m^{-2}) from mouldboard plough + rotavator respectively. Minimum weeds fresh weight (116.35 g m^{-2}) at 45 days after sowing was recorded from chisel plough + rotavator. Khan *et al*. (2017) revealed that chisel plough significantly decreased weeds fresh weight. Gul *et al*. (2011) and Swanton *et al*. (2000) reported significantly lowest weeds fresh weight at different tillage operations especially with chisel plough. Among weed control methods, significantly lowest weeds fresh weight (91.03 g m^{-2}) was recorded from weed management with application of herbicide (Nicosulfuron) followed by 128.44 g m^{-2} fresh weeds biomass recorded from treatment of two hoeings i.e. hoeing 15 and 30 DAS. Highest weeds fresh weight (238.45 g m^{-2}) at 45 days after sowing was recorded from control. The lowest weeds fresh weight was obtained from application of Nicosulfuron. It may be due to the persistence of herbicide that controlled newly emerging weeds in treated plots. Khatam *et al*. (2013) and Kandil and Kordy (2013) reported significantly lowest weeds biomass with application of post-emergence herbicides.

Weeds dry weight (g m^{-2}) at 45 days after sowing (DAS)

Table-2 presents data regarding weeds dry weight (g m^{-2}) at 45 days after sowing (DAS) in maize crop as affected by different tillage practices and weeds control methods. The treatment of tillage practices and weed control methods on weeds dry weight (g m^{-2}) at 45 days after sowing (DAS) was significant (P≤0.05) while their interaction was non-significant. The treatment of chisel plough + rotavator produced minimum dry weight of weeds (38.69 g m^{-2}) at 45 DAS followed by mouldboard plough + rotavator with weeds dry weight of 47.42 g m^{-2}. The treatment of rotavator produced maximum dry weight of weeds (66.16 g m^{-2}) at 45 days after sowing. Among various tillage operations chisel plough + rotavator resulted in significantly lowest weeds dry matter and population of total weeds. The superiority of chisel plough to decrease population and dry matter of weeds could be ascribed to presence of significantly lowest number of weeds in soil as compared to other tillage operation which helped the crop to take lead in its growth and establishment and suppressing the weeds growth (Khan *et al*., 2017). Marwat *et al*. (2007) reported that deep tillage suppressed weeds growth and resulted in less weeds dry weight. Among weed control methods, minimum weeds dry weight (30.34 g m^{-2}) was recorded with the application of herbicide Nicosulfuron followed by weeds dry weight of 42.81 g m^{-2} from treatment of hoeing. Maximum weeds dry weight (80.83 g m^{-2}) at 45 DAS was obtained from control. Quee *et al*. (2018) reported that total weed biomass was significantly higher in un-weeded plots compared to other weed control treatments. Ali *et al*. (2014) and Tesfay *et al*. (2014) reported significant variation in dried weeds biomass with different weeds control methods. They concluded that weeds dry weight was significantly reduced by application of different herbicides.

Table-2. Weeds m^{-2}, weeds fresh weight (g m^{-2}) and weeds dry weight (g m^{-2}) at 45 DAS in maize crop as affected by different tillage practices and weeds control methods.

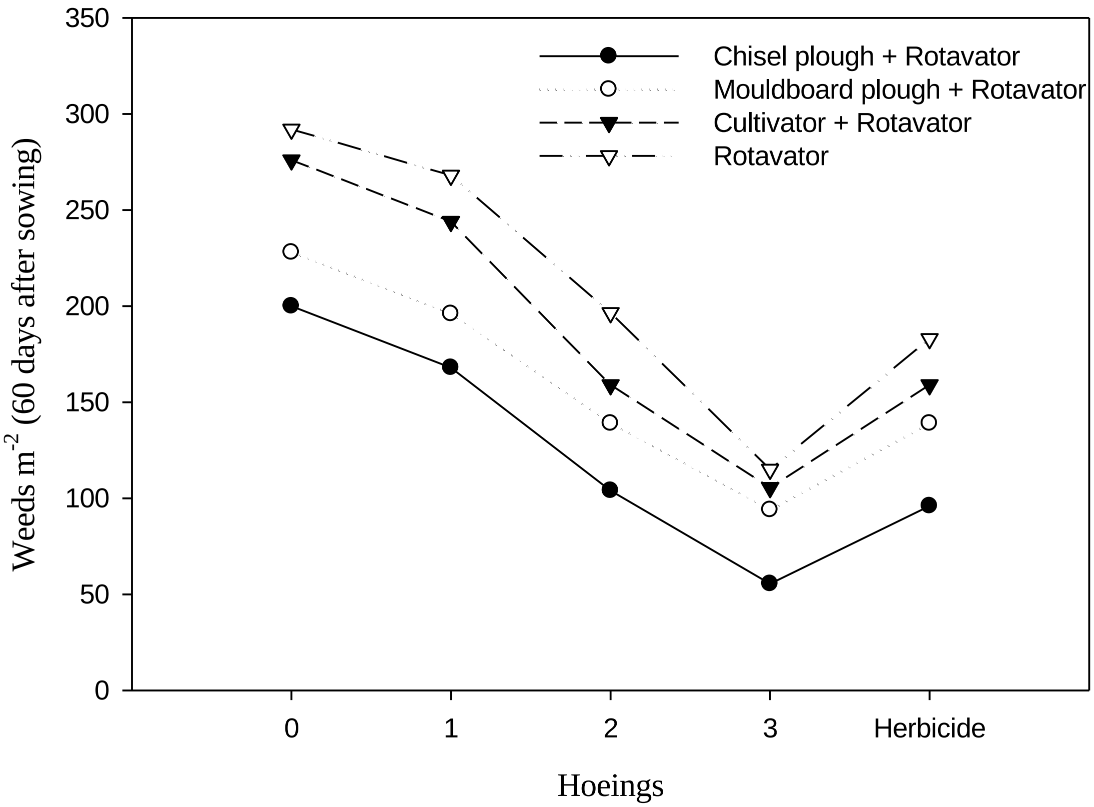
Tillage practices	Weeds m^{-2} at 45 DAS	Weeds fresh weight (g m^{-2}) at 45 DAS	Weeds dry weight (g m^{-2}) at 45 DAS
Chisel plough + Rotavator	101 d	116.35 d	38.69 d
Mouldboard plough + Rotavator	127 c	142.68 c	47.42 c
Cultivator + Rotavator	158 b	180.36 b	59.90 b
Rotavator	182 a	198.90 a	66.16 a
Weeds control methods			
Control	206 a	238.45 a	80.83 a
Hoeing 15 DAS	182 b	180.38 b	58.19 b
Hoeing 15 and 30 DAS	98 c	128.44 c	42.81 c
Nicosulfuron	82 d	91.03 d	30.34 d
$LSD_{(0.05)}$ for TP	22	16.55	5.57

$LSD_{(0.05)}$ for WCM	14	18.66	6.21
TP x WCM	NS	NS	NS

Means of same categories followed by different letters are statistically different at 5% level of probability.
DAS = Days after sowing TP = Tillage practices WCM = Weed control methods
NS = non-significant

Weeds m^{-2} at 60 days after sowing (DAS)

Table-3 reveals number of weeds m^{-2} at 60 days after sowing (DAS) in response to different tillage practices and weed control methods. Statistical analysis of the data indicated that tillage operations and weed control methods had significantly ($P \leq 0.05$) affected number of weeds m^{-2}. The interaction of tillage practices and weed control methods was also significant (Figure 2). Maximum weeds m^{-2} (210 weeds m^{-2}) was observed in rotavator followed by cultivator + rotavator (189 weeds m^{-2}). Minimum number of weeds m^{-2} (125 weeds m^{-2}) at 60 days after sowing was recorded from chisel plough + rotavator. The superiority of chisel plough to decreased weeds population at 60 days after sowing could be attributed to presence of significantly less number of weeds in soil as compared to other tillage operation which helped the crop to take lead in its growth and establishment and suppressing the weeds growth. Khan *et al*. (2017); Demjanova *et al*. (2009) and Arif *et al*. (2007) revealed that tillage practice (chisel plough) reduced number of weeds. Significant variations were observed in weeds m^{-2} with different weed control strategies. Lowest number of weeds m^{-2} (93 weeds m^{-2}) 60 DAS was recorded from three hoeings i.e. hoeing 15, 30 and 45 days after sowing followed by weeds m^{-2} (144 weeds m^{-2}) from the application of herbicide, nicosulfuron. Highest weeds m^{-2} (249 weeds m^{-2}) 60 days after sowing was recorded from control. Sampaio *et al*. (2015); Ali *et al*. (2014) and Hassan and Ahmed (2005) reported that different weed control methods specifically with hoeing significantly reduced weed population including both grassy and broad-leaf weeds in maize crop. Weeds m^{-2} decreased with increasing hoeing numbers and tillage depth (Figure 2). Minimum weeds density was recorded for three hoeings (hoeing 15, 30 and 45 days after sowing) with using chisel plough + rotavator for seedbed preparation.



0= Control, 1= hoeing 15 days after sowing, 2= hoeing 15+ 30 days after sowing, 3= hoeing 15 + 30 + 45 days after sowing, Herbicide= Nicosulfuron

Figure 2**.** Interaction of tillage practices and weeds control methods for weeds m^{-2} at 60 days after sowing (DAS).

Weeds fresh weight (g m^{-2}) at 60 days after sowing (DAS)

Weeds fresh weight (g m^{-2}) at 60 DAS was significantly affected by different tillage practices and weed control methods (Table-3). The interaction of tillage practices and weed control methods was non-significant. Treatment of chisel plough + rotavator indicated minimum weeds fresh weight (252.56 g m^{-2}) followed by mouldboard plough + rotavator (312.82 g m^{-2}). Maximum weeds fresh weight (370.22 g m^{-2}) at 60 days after sowing was recorded from treatment of rotavator. Khan *et al*. (2017) revealed that chisel plough significantly decreased weeds fresh weight as compared to operation of rotavator. Nakamoto *et al*. (2006) and Swanton *et al*. (2000) reported that most of the weed seeds (71%) are concentrated in soil at the depth of 10-15 cm which can be disturbed greatly by deep tillage (chisel plough) operations. Treatment of hoeing 15, 30 and 45 days after sowing (DAS) produced significantly lowest fresh weeds biomass (173.97 g m^{-2}) followed by application of herbicide (Nicosulfuron) with fresh weeds biomass of 253.02 g m^{-2}. Highest fresh weeds biomass (505 g m^{-2}) at 60 days after sowing was recorded from control. Sampaio *et al*. (2015); Khatam *et al*. (2013) and Kandil and Kordy (2013) revealed that various weed control methods at different stages have significantly reduced weeds fresh weight.

Weeds dry weight (g m^{-2}) at 60 days after sowing (DAS)

The weeds dry weight (g m^{-2}) at 60 DAS in maize was significantly affected by different tillage practices and weed control methods (Table-3). The interaction of tillage practices and weed control methods for weeds dry weight at 60 DAS was non-significant. Tillage practice of chisel plough + rotavator produced minimum weeds dry weight (80.61 g m^{-2}) at 60 days after sowing followed by mouldboard plough + rotavator with weeds dry weight of 99.37 g m^{-2}. Maximum weeds dry weight (117.54 g m^{-2}) at 60 DAS was recorded from the treatment of rotavator. Khan *et al*. (2017) stated that chisel plough resulted in significantly lowest dry weight of total weeds. The supremacy of chisel plough to decrease population and dry matter of weeds could be ascribed to deep burying the weed seeds in soil as compared to other tillage operation which ultimately resulted in lowest weeds dry weight. Marwat *et al*. (2007) reported that deep tillage suppressed weeds growth which produced less weeds dry weight. Among weed control methods, minimum weeds dry weight (56.12 g m^{-2}) at 60 days after sowing (DAS) was recorded from hoeing 15, 30 and 45 DAS followed by weeds dry weight (81.62 g m^{-2}) from the application of herbicide Nicosulfuron. Maximum weeds dry weight (162.90 g m^{-2}) at 60 days after sowing was recorded from control. Ali *et al*. (2014); Tesfay *et al*. (2014) and Khatam *et al*. (2013) revealed significant variation in weeds dry weight. They reported that weeds dry weight was significantly reduced by different weed control methods.

Table-3. Weeds m^{-2}, weeds fresh weight (g m^{-2}) and weeds dry weight (g m^{-2}) at 60 DAS in maize crop as affected by different tillage practices and weeds control methods.

Tillage practices	Weeds m^{-2} at 60 DAS	Weeds fresh weight (g m^{-2}) at 60 DAS	Weeds dry weight (g m^{-2}) at 60 DAS
Chisel plough + Rotavator	125 d	252.56 c	80.61 c
Mouldboard plough + Rotavator	159 c	312.82 b	99.37 b
Cultivator + Rotavator	189 b	361.54 a	114.72 a
Rotavator	210 a	370.22 a	117.54 a
Weeds control methods			
Control	249 a	505.00 a	162.90 a
Hoeing 15 DAS	219 b	424.91 b	129.32 b
Hoeing 15 and 30 DAS	150 c	264.53 c	85.33 c
Hoeing 15, 30 and 45 DAS	93 d	173.97 d	56.12 d
Nicosulfuron	144 c	253.02 c	81.62 c
$LSD_{(0.05)}$ for TP	21	37.72	11.89
$LSD_{(0.05)}$ for WCM	10	21.92	6.94
TP x WCM	*	NS	NS

Means of same categories followed by different letters are statistically different at 5% level of probability.

DAS = Days after sowing   TP = Tillage practices   WCM = Weed control methods

NS = non-significant   * = Represent significance at $P \leq 0.05$ level of probability

Plant height (cm)

Plant height of maize was significantly ($P \leq 0.05$) affected by various tillage operations and weed control methods (Table-4). Interaction of tillage practices and weeds control methods was non-significant. The treatment of chisel plough + rotavator produced tallest plants (221.22 cm) followed by mouldboard plough + rotavator with plant height of 213.98 cm. Plots ploughed with rotavator produced shortest plants (199.26 cm). Maximum plant height attained by chisel plough + rotavator might be due to effective management of weeds and breaking of soil compacted and hard layer with chisel plough led to well aerated soil which subsequently enhanced root growth, efficient utilization of soil moisture and nutrients by the plants particularly in early growth stages of crop, thus enhanced crop growth. Anjum *et al*. (2014) and Memon *et al*. (2012) revealed that chisel plough increased plant height of maize crop. Zaremohazabieh *et al*. (2017) reported that plant height was reduced with no tillage as compared with conventional tillage. Among weed control methods, maximum plant height (226.41 cm) was attained from hoeing 15, 30 and 45 days after sowing (DAS) followed by plant height of 215.37 cm from treatment of hoeing 15 and 30 DAS. Shortest plants (196.66 cm) were recorded from control. The increase in plant height by hoeing 15, 30 and 45 days after sowing might be due to less weeds infestation and low crop-weeds competition for moisture, solar radiation, space and nutrients. Apparently, with three weedings, weeds were weakened to such an extent that crops were given a competitive edge. Purba and Nasution, (2018) reported that plant height of maize was significantly higher in plots where weeds were controlled. Din *et al*. (2016); Ali *et al*. (2015) and Tahir *et al*. (2009) reported that weeds management particularly with hoeing enhanced plant height of maize crop.

Grain rows ear^{-1}

Tillage practices and weeds control methods significantly ($P \leq 0.05$) affected grain rows ear^{-1} of maize (Table-4). Interaction of tillage practices and weeds control methods was however non-significant. Maximum number of grain rows ear^{-1} (16 rows) were produced by plots cultivated with chisel plough + rotavator followed by mouldboard plough + rotavator (14 rows). Minimum grain rows ear^{-1} (13 rows) were recorded from rotavator alone. Highest number of grain rows ear^{-1} might be due to improved environment of soil with deep tillage operation followed by rotavator which resulted into enhanced crop growth and development owing to optimum management of weeds. Shahid *et al*. (2016); Javeed *et al*. (2014) and Wasaya *et al*. (2011) stated that different tillage practices significantly affected number of grain rows ear^{-1}. They reported that tillage practices with chisel plough resulted in more number of grain rows ear^{-1} in maize crop. Among weed control methods, hoeing 15, 30 and 45 days after sowing (DAS) produced highest number of grain rows ear^{-1} (16 rows) as compared to other hoeings and herbicide application. Minimum number of grain rows ear^{-1} (12 rows) were recorded from control. Highest grain rows ear^{-1} obtained from treatment of hoeing 15, 30 and 45 DAS might be due to the maximum water and nutrients availability due to less weeds competition in the root zone. Tahir *et al*. (2009) and Sulewska *et al*. (2006) revealed that control of weeds through hoeing in maize improved number of grain rows ear^{-1}.

Shelling percentage (%)

Tillage operations and weed control methods showed a significant ($P \leq 0.05$) effect on shelling percentage of maize (Table4). The interaction of tillage practices and weed control methods was non-significant. Chisel plough + rotavator produced maximum shelling percentage (78.14%) followed by shelling percentage of 76.88% (cultivator + rotavator). The rotavator alone showed minimum shelling percentage (73.71%). Among weed control methods, hoeing 15, 30 and 45 days after sowing produced highest shelling percentage (79.11%) followed by shelling percentage (76.62%) recorded from hoeing 15 and 30 days after sowing. Lowest shelling percentage (72.36%) was recorded from control. Wasaya *et al*. (2012) reported that different tillage operations significantly improved shelling percentage of maize crop.

Table-4. Plant height (cm), grain rows ear^{-1}, and shelling percentage (%) of maize crop as affected by different tillage practices and weeds control methods.

Tillage practices	Plant height (cm)	Grain rows ear^{-1}	Shelling percentage (%)
Chisel plough + Rotavator	221.22 a	16 a	78.14 a
Mouldboard plough + Rotavator	213.98 b	14 b	75.63 b
Cultivator + Rotavator	206.03 c	14 b	76.88 ab
Rotavator	199.26 d	13 c	73.71 c
Weeds control methods			
Control	196.66 d	12 c	72.36 c
Hoeing 15 DAS	207.41 c	14 b	75.77 b
Hoeing 15 and 30 DAS	215.37 b	14 b	76.62 b
Hoeing 15, 30 and 45 DAS	226.41 a	16 a	79.11 a
Nicosulfuron	204.75 c	14 b	76.58 b
$LSD_{(0.05)}$ for TP	5.97	0.89	1.54
$LSD_{(0.05)}$ for WCM	3.81	0.7	2.05
TP x WCM	NS	NS	NS

Means of same categories followed by different letters are statistically different at 5% level of probability.
DAS = Days after sowing TP = Tillage practices WCM = Weed control methods
NS = non-significant * = Represent significance at P≤0.05 level of probability

CONCLUSION

It is concluded that preparing seedbed for maize with chisel plough + rotavator significantly reduced weeds infestation in terms of number of weeds m^{-2} and weeds dry weight. Among weed control methods, lowest weeds population and weeds dry weight was recorded from the treatment of hoeing 15, 30 and 45 days after sowing. The seedbed preparation with chisel plough + rotavator with three manual hoeing i.e. hoeing 15, 30 and 45 days after sowing was found affective in controlling weeds population in maize crop.

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