Research Article

EFFECTS OF SPACING AND WEED MANAGEMENT PRACTICES IN WINTER MAIZE IN RAMPUR, CHITWAN

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ABSTRACT
Maize is sensitive to weed infestation; losses in crop yield vary from 28-100%. Manual weeding is the most dominant method in Nepal, however, a majority of the farmers still does not adopt any specific method of weed control. An experiment was conducted to evaluate the influence of plant spacing and weed management practices on weed dynamics and yield of maize, during the winter season of 2016/17 at National Maize Research Program (NMRP), Rampur, Chitwan, Nepal. The experiment was done using split plot design with three replication; main plot factor was plant density (66666 and 83333 plants/ha),and sub-plot factors was weed management practices viz. weedy check, weed-free, two hand weeding at 30 and 60 DAS, rice straw mulch, black plastic mulch, Atrazine @ 0.75 kg a.i./ha + Pendimethalin @ 0.5 kg a.i./ha, Atrazine @ 0.75 kg a.i./ha + Pendimethalin @ 0.5 kg a.i./ha followed by hand weeding at 30 DAS, and Atrazine @ 0.75 kg a.i. /ha + Pendimethalin @ 0.5 kg a.i./ha followed by 2,4-D @1.5 L a.i./ha at 35 DAS. The plant density did not show significant effect on weed density, weed dry weight, Weed Control Efficiency, Weed Index, and grain yield. Use of black plastic mulch was the most effective to reduce weed density and dry weight. The higher Weed Control Efficiency (97.7, 96.4, 95.9 and 89.6% at 30, 60, 90 DAS and at harvest), and lower Weed Index (-2.9%) were also found with the use of black plastic mulch. As compared to weed-free condition, weed caused grain yield loss up to 61.5% in the weedy condition. Accordingly, highest grain yield was achieved with the use of black plastic mulch (5.1 t ha^{-1}) followed by weed-free (5.0 t ha^{-1}) condition and with the use of rice straw as mulch (4.7 t ha^{-1}). This information could be useful in developing weed management packages in maize.

Key words: mulch, weed dynamics, weed control efficiency, weed index

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops in the world agricultural economy both as food and fodder crop and because of its high productivity over other major cereals rice and wheat, it is also considered as queen of cereal. It is called as a miracle crop with very high genetic yield potential, among other cereals. Maize production ranks first among other cereals (wheat and rice) in the world, but harvest area is lower than wheat. It is grown in 188 million ha with a production of 1060 million tones all around the world in 2016 (FAO, 2018).

Maize is the second most important crop after rice in terms of area and production in Nepal. It is a way of livelihood for the majority of the farmers in the hills of Nepal. It is grown in 891,583 hectares of land with the production of 2,231,517 MT and yield of 2,503 kg ha^{-1} (MoAD, 2016). Its share on Agricultural Gross Domestic Product (AGDP) is 7.04% and on Gross Domestic Product (GDP) share is 2.20% (MoF Economic survey, 2016).

Weed is a plant where and when it is not desired and not intentionally sown, and which compete with crop variously. Glowacka (2011) suggested that weeds are serious competitors to crop plants for nutrients and their share in the total uptake of macro elements from the soil was like 35% K, 27.3% Ca, and 27.4% Mg. Weeds cause high losses of maize yield by 35% observed by (Dangwal, Singh, Sharma, & Singh,2011). The weed infestation in spring maize reduced the grain yield by 37.17% (Shrivastav et al., 2015). Manual weeding is the most dominant method in Nepal however a majority of the farmers still do not adopt any specific method for weed control. Karki, BK, & Mishra (2010) reported that 48% grain yield of maize reduces due to weed infestation in the hills of Nepal.

Several types of research proved more and integrated researches are needed for weed management in maize at farmer's field to disseminate an economically viable and environment-friendly management practices. Thus, for increasing maize yield need better crop management practices including weed control strategies. Since there are various weed control methods, select suitable weed management practices according to specific crop, time and location. In Nepalese condition, the modern weed management strategies are not adopted by farmers under maize-based system except farmers weed management practice of two times hand weeding at 30 DAS and 45/60 DAS. The rapidly increasing demand for maize is driven by an increase in demand for direct human consumption in the hills as a staple food crops and for livestock and poultry feeds in terai and inner-terai areas to meet the increasing demand of feed for sustaining the poultry industry and also the year-round demand of the green maize for consumption in the cities. There are 101 animal feed industries in Nepal and needs 1800 metric tons of maize every day. In the recent years, Nepal imported maize annually worth of Rs 12 billion (Madhusudan, 2019).

Fanadzo et al., (2010) observed that narrow rows of 45 cm reduced weed biomass by 58%. And, increasing the plant population from 40000 to 60000 plants ha^{-1} resulted in a 30% grain yield increase. Jiang, Wang, Wu, Dong, Liu, & Zhang(2013) found that the maize grain yield and dry matter accumulation were 5.0% and 8.4% lower in the narrow plant spacing than the normal plant spacing.Xu, Li, Liu, Zhou, Tao, Wang, & Zhao(2015) suggested that plastic film mulch significantly increased the grain yield by 15-26% in the dry years as compared to the control. (Mohtisham et al., 2013) observed that the densities and dry weight of weeds were reduced by the application of mulches.Shah et al. (2014) reported that the minimum number of weeds (128 m^{-2}) and (164 m^{-2}) were recorded in black plastic and weeds as mulch. Similarly, maximum grain yields (1.91 and 1.85 t ha^{-1}) were recorded in black plastic and weeds as mulch.

Only the best and effective weed management practices would reduce the crop yield loss and increase productivity of maize crop. This research was conducted to evaluate the effect of plant spacing and weed management practices on weed dynamics, crop growth and yield of winter maize.

MATERIAL AND METHODS

Experimental site

An experiment was conducted at the research block of National Maize Research Program (NMRP), Rampur, Chitwan during the winter season of 2016/17 (August to April). The area representing inner terai region of Nepal has sub-tropical climate.

Physiochemical properties of experimental soil

Soil samples were randomly taken from different places at depth of 0-15 and 15-30 cm using soil auger and made composite in order to know the preliminary physio-chemical properties of the experimental soil. The soil samples were sent to Regional Soil Testing Laboratory, Hetauda, Makawanpur. The total nitrogen was determined by Kjeldahl distillation unit, available phosphorus by spectrophotometer and available potassium by flame photometer, Organic matter was determined by Walky and Black method (1934) and pH (1:1 soil: water suspension) by Beckman Glass Electrode pH meter. Soil pH was slightly acidic (5.75) with medium organic matter (2.81%) and total nitrogen (0.09%). The available K was medium (180.42 kg ha^{-1}).

Climatic condition during experimentation

Monthly and daily average data were taken on various weather parameters i.e. maximum and minimum temperatures, total rainfall and relative humidity and it was recorded by metrological station of NMRP, Rampur Chitwan (Figure 1).The total rainfall of 272.80 mm was received during the entire period of experimentation. The highest rainfall was recorded during September fourth week to October first week (108.4 mm) and there was no rainfall in the month of November first to January third week (0 mm). During the crop cycle, the maximum mean temperature was ranged from 23.4 to 33.0^{0}C with the mean of 28.1^{0}C. It was highest (33.0^{0}C) during the third week of April and the lowest (23.4^{0}C) during the third week of December. The average relative humidity increased from the first week of October (86.7%) to highest at first week of December (93.5) and then decreased attaining lowest at first week of March (67.2%).

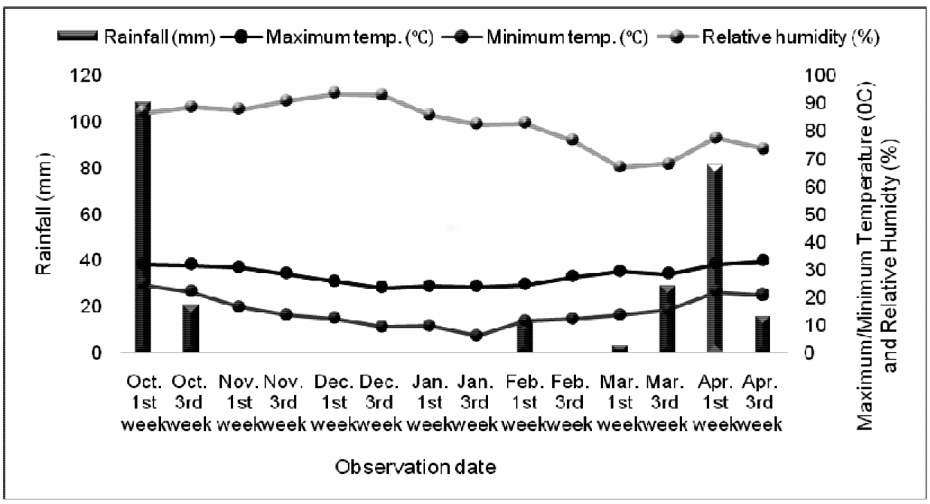

Figure 1. Weather condition during the trial at NMRP, Rampur, Chitwan, Nepal
(**Source**: NMRP, 2017)

Experimental details

The experiment was laid out in split plot design having three replications.The main plot factor including two plant density (66666 and 83333 plants/ha) and sub-plot factors including eight weed management practices viz; weedy check, weed-free, two hand weeding at 30 and 60 DAS, rice straw mulch, black plastic mulch, Atrazine @ 0.75 kg a.i./ha + Pendimethalin @ 0.5 kg a.i./ha, Atrazine @ 0.75 kg a.i./ha + Pendimethalin @ 0.5 kg a.i./ha followed by hand weeding at 30 DAS, and Atrazine @ 0.75 kg a.i. /ha + Pendimethalin @ 0.5 kg a.i./ha followed by 2,4-D @1.5 L a.i./ha at 35 DAS.

Maize variety "Deuti" was sown by maintaining 25 cm and 20 cm distance between plant to plant with row to row distance of 60 cm. The recommended dose of inorganic fertilizers i.e.@ 120:60:40 kg N, P_2O_5 and K_2O ha^{-1} were applied through Urea (46% N), DAP (18% N and 46% P_2O_5) and MOP (60% K_2O).

Herbicide application and weed management practices

Black plasticwas kept in the plot and covered with soil in the border area of the plot, and making whole for sowing the maize seed.The crop residue (rice straw) were kept between maize rows soon after the sowing process. In farmers' practice of weeding hand weeding and hoeing was done at 30 and 60 DAS. The pre-emergence tank mix application of Atrazine @ 0.75 kg a.i. ha^{-1} + Pendimethaline @ 0.5 kg a.i. ha^{-1}, pre-emergence tank mix application of Atrazine @ 0.75 kg a.i. ha^{-1} + Pendimethaline @ 0.5 kg a.i. ha^{-1} followed by hand weeding at 30 DAS, and pre-emergence tank mix application of Atrazine @ 0.75 kg a.i. ha^{-1} + Pendimethaline @ 0.5 kg a.i. ha^{-1} followed by 2,4-D Ethyl Ester @1.5 L a.i. ha^{-1} were applied as herbicide treatments.

Measurements

Data were recorded on weeds density m^{-2}, weed dry weight (g m^{-2}), weed control efficiency (%), weed index (%), grain yield (ton ha^{-1}), stover yield (ton ha^{-1}) and grain yield (ton ha^{-1}). Weed density and dry weight was recorded at 30, 60, 90 days after sowing (DAS).From quadrate of 0.6 x 0.5 m^2total number of weeds, broad-leaf, Narrow-leaf and sedges were counted. The grain yield was determined by harvesting three central rows as net plot from each plot. The ears from harvested plants were detached, threshed, weighed and the values were converted to ton ha^{-1}. Ten cobs were selected from each net plot to analyze the yield attributing characters. Thousand grains were counted at random from the bulk of net plot yield of eachplot and weighed in grams with the help of digital balance.

Weed Control Efficiency (WCE)

The WCE was worked out by using the formula suggested by Mani, Malla, & Gautam(1973) and expressed in percentage.

$$\mathbf{WCE\% = \frac{WP_c - WP_t}{WP_c} x\ 100}$$

Where,

WP_c = Weed population (No m^{-2}) in control plot

WP_t = Weed population (No m^{-2}) in treated plot

Weed Index (Weed Index)

WI was calculated by using the formula given by Gill (1969).

$$WI\ (\%) = \frac{Ywf - Yt}{Ywf}\ X\ 100$$

Where, Y_{wf} is the crop yield in weed-free check,

Y_t is the crop yield in treatments.

Statistical analysis

The recorded data were compiled and analyze by statistical tool GenStat package and MS-EXEL. ANOVA was constructed to test the significant difference for each parameter at 5% level of significance. Duncan Multiple Range Test (DMRT) was used for mean separation as prescribed by (Gomez, & Gomez, 1984). The data of weed were subjected to square root transformation to normalize their distribution (Gomez, & Gomez, 1984).

RESULTS AND DISCUSSION

Weed density (m^{-2}) and weed dry weight (g m^{-2})

The weed density and weed dry weight was not influenced by the plant density and at par with each other at all growth stages of winter maize respectively. Plant density reduced by reducing row spacing give better result than reducing plant to plant spacing. There is low space for weed growth in reducing row distance.

The effect of different weed management practices on weed density was significant (Table1).The lowest weed density and dry weight was observed in the black plastic mulch treated plot at all growth stages of winter maize.Which was statistically differ than all other weed management practices. The black plastic blocks the light and provides the minimum space for weed germination and growth. Shah et al., (2014) also reported that the minimum number of weeds was recorded while using black plastic mulch.

Significantly higher weed density and dry weight was found at all growth stage of winter maize in the weedy check (28.5, 28.2, 20.9 and 18.1no m^{-2}; 12.6, 14.1, 15.7 and 15.2 g m^{-2} at 30, 60, 90 DAS and at harvest, respectively).Highest number of weeds and dry weight in weedy check was due to uncontrolled weeds germination and growth in comparison to all weed control treatments. The higher weeds density in weedy check may be due to the open soil surface and niches available to weeds for germination and free growth.

Table 1. Weed density (number, m^{-2}) as influenced by plant density and weed management practices in winter maize at NMRP, Rampur, Chitwan, Nepal, 2016

	Weed density (number of weeds per square meter)			
Treatments	**30 DAS**	**60 DAS**	**90 DAS**	**At harvest**
Plant density				
66666 plants ha^{-1}	17.8 (407.1)	16.1 (343.3)	12.6	11.4
83333 plants ha^{-1}	17.1 (379.7)	16.2 (346.0)	12.9	11.9
SEm (±)	1.0	0.9	0.6	0.3
LSD (=0.05)	NS	NS	NS	NS
CV, %	10.3	9.9	8.0	4.6
Weed management practices				
The weedy check	28.6^{a} (809.4)	28.2^{a} (820.0)	20.9^{a} (439.4)	18.13^{a}(328.6)
Weed-free	0.7^{f} (0.0)	0.7^{e} (0.0)	0.7^{f} (0.0)	0.7^{e} (0.0)
Two HW (30 and 60 DAS)	26.6^{a} (710.0)	15.2^{c} (231.4)	15.4^{c} (238.2)	11.9^{c} (142.2)
Crop residue mulch (rice straw)	18.8^{cd} (352.5)	18.8^{bc} (381.7)	12.81^{d} (166.2)	13.7^{b} (189.4)
Black plastic mulch	4.3^{e} (18.5)	5.1^{d} (25.8)	4.2^{e} (18.7)	5.7^{d} (34.4)
Atrazine + Pendimethalin	22.3^{b} (503.1)	22.1^{b} (505.6)	18.5^{b} (347.1)	17.8^{a} (316.7)
Atrazine + Pendimethalin + HW at 30 DAS	17.8^{d} (326.9)	17.1^{c} (292.5)	16.4^{c} (271.0)	12.2^{c} (150.3)
Atrazine + Pendimethalin +2,4-D 35 DAS	20.4^{bc} (426.4)	22.0^{b} (500.1)	13.3^{d} (181.8)	12.8^{bc} (164.1)
SEm (±)	0.8	1.3	0.6	0.4
LSD (=0.05)	2.2	3.8	1.7	1.2
CV, %	10.7	20.0	11.3	9.0
Grand mean	393.4	344.6	207.8	165.7

Note: Data subjected to square-root (√X+1) transformation; Figures in parenthesis are original values; Mean separated by DMRT and columns represented with the same letter (s) are non-significant at% level of significance. Note: PE (The pre-emergence), Post (Post-emergence); DAS (Days after sowing); HW (Hand weeding); W (Weed management practices)

Table 2. Weed dry weight (g m^{-2}) as influenced by plant density and weed management practices in winter maize at NMRP, Rampur, Chitwan, Nepal, 2016

Treatments	Weed dry weight (g m^{-2})			
	30 DAS	60 DAS	90 DAS	At harvest
Plant density				
66666 plants ha^{-1}	8.4 (90.9)	7.1 (77.4)	8.3 (94.4)	10.1 (123.1)
83333 plants ha^{-1}	9.2 (108.4)	7.2 (77.4)	8.2 (88.4)	9.5 (108.6)
SEm (±)	0.7	0.5	0.3	0.1
LSD (=0.05)	NS	NS	NS	NS
CV, %	14.2	10.9	5.9	2.0
Weed management practices				
The weedy check	12.6^{a} (157.3)	14.1^{a} (198.6)	15.7^{a} (247.0)	15.2^{a} (232.1)
Weed-free	0.7^{c} (0.0)	0.7^{e} (0.0)	0.7^{f} (0.0)	0.71^{e} (0.00)
Two HW (30 and 60 DAS)	12.5^{a} (157.3)	3.5^{d} (11.9)	6.9^{d} (48.1)	11.47^{b} (133.73)
Crop residue mulch (rice straw)	9.8^{b} (99.4)	9.4^{c} (89.4)	10.3^{c} (107.1)	12.25^{b} (154.45)
Black plastic mulch	1.5^{c} (1.9)	1.5^{e} (1.8)	1.7^{e} (2.8)	5.55^{d} (30.86)
Atrazine + Pendimethalin	11.3^{ab} (131.3)	12.6^{b} (161.4)	11.9^{b} (142.6)	11.28^{bc} (127.09)
Atrazine+Pendimethalin+HW,30 DAS	10.7^{b} (119.7)	3.2^{d} (10.1)	7.8^{d} (60.8)	12.21^{b} (148.69)
Atrazine+Pendimethalin+2,4-D ,35 DAS	11.4^{ab} (130.4)	12.1^{b} (146.4)	11.1^{bc} (122.7)	9.92^{c} (99.75)
SEm (±)	0.5	0.4	0.3	0.50
LSD (=0.05)	1.5	1.0	0.9	1.46
CV, %	14.1	12.4	9.5	12.50
Grand mean	99.7	77.4	91.4	115.83

Note: Data subjected to square-root (√X+1) transformation; Figures in parenthesis are original values; Mean separated by DMRT and columns represented with the same letter (s) are non-significant at% level of significance. Note: PE (The pre-emergence), Post (Post-emergence); DAS (Days after sowing); HW (Hand weeding); W (Weed management practices)

Weed control efficiency (WCE) and Weed Index (WI)

WCE was not significantly affected by plant densities. WI recorded in lower plant density (27.6%) was higher in comparison to higher plant density (25.8%). This indicates that grain yield loss due to weed competition was increased by 1.8% in lower density.

The values weed control efficiency recorded in black plastic mulch (97.7, 96.4, 95.9 and 89.6%) were significantly higher as compared to all other weeding treatments at 30, 60, 90 DAS and harvest, respectively. Lowest WI was obtained in black plastic mulch (-2.9). Maize grain yield was not reduced by weed in black plastic treated plot and yield was higher than weed free condition. The WCE recorded in two hand weeding (12.4%) at 30 DAS was significantly lower than other weed management practices except black plastic mulch. The WCE in tank mix application of atrazine and pendimethalin followed by 2,4-D at 35 DAS and tank mix application of atrazine and pendimethalin (47.6 and 37.9%) were statistically at par at 30 DAS. Further, with respect to weed management methods, significantly higher weed index (WI) was found in the weedy check (61.5%) as compared to weed-free condition and all other weeding treatments. It reflects that 61.5% of grain yield was reduced by uncontrolled weed growth in the weedy check. Further, Karki et al., (2010) reported that 48% grain yield of maize reduces due to weed infestation in the hills of Nepal.

Table 3. Weed control efficiency (%) and weed index as influenced by plant density and weed management practices in winter maize at NMRP, Rampur, Chitwan, Nepal, 2016

Treatments	Weed control efficiency (WCE)%				Weed Index (WI)%
	30 DAS	60 DAS	90 DAS	At harvest	
Plant density					
66666 plants ha^{-1}	36.5	46.2	37.4	38.7	27.6
83333 plants ha^{-1}	41.6	38.7	42.5	35.3	25.8
SEm (±)	3.39	9.4	2.67	0.90	3
LSD (=0.05)	NS	NS	NS	NS	NS
CV, %	15	38.4	11.60	4.20	19.4
Weed management practices					
The weedy check	-	-	-	-	61.52^{a}
Weed-free	-	-	-	-	-
Two HW (30 and 60 DAS)	12.4^{e}	67.5^{b}	45.8^{c}	56.7^{b}	18.2^{bc}
Crop residue mulch (rice straw)	56.6^{bc}	47.8^{bc}	61.0^{b}	42.2^{c}	6.5^{cd}
Black plastic mulch	97.7^{a}	96.4^{a}	95.9^{a}	89.6^{a}	-2.9^{d}
Atrazine + Pendimethalin	37.9^{d}	35.9^{c}	20.0^{d}	3.5^{d}	55.1^{a}
Atrazine + Pendimethalin + HW at 30 DAS	60.3^{b}	57.8^{b}	38.5^{c}	54.3^{b}	28.8^{b}
Atrazine + Pendimethalin +2,4-D 35 DAS	47.6^{cd}	34.0^{c}	58.8^{b}	49.6^{bc}	46.3^{a}
SEm (±)	3.6	6.7	3.7	2.9	5.0
LSD (=0.05)	10.4	19.5	10.7	8.3	14.6
CV, %	22.5	38.8	22.5	19.0	46.2
Grand mean	39.1	42.4	40.0	37.0	26.7

Note: Mean separated by DMRT and columns represented with the same letter (s) are non-significant at% level of significance. Note: PE (The pre-emergence), Post (Post-emergence); DAS (Days after sowing); HW (Hand weeding); W (Weed management practices); WCE (Weed Control Efficiency); WI (Weed Index)

Grain and stover yield

The grain and stover yield of maize variety 'Deuti' was not significantly influenced by plant densities. Grain yield found significant differences among weed management practices. Significantly higher grain yield was obtained in black plastic mulch (5.1 t ha^{-1}) over all other weeding treatments except weed-free condition (5.0 t ha^{-1}) and rice straw mulching (4.7 t ha^{-1}) which were at par to with it. The stover yield recorded in black plastic mulch (6.4 t ha^{-1}) was significantly superior over all other weeding treatments. The lower weed density, weed dry weight and weed index, and higher weed control efficiency finally obtained higher grain and stover yield. Khan, & Parvej (2011) also reported maximum grain yield in Primextra Gold 720SC, polyethylene (black), hand weeding and polyethylene (white) with grain yield of 2.98, 2.48, 2.06 and 2.03 t ha^{-1}, respectively.Shah et al. (2014) also found maximum grain yields in black plastic. Similarly, the polyethylene film and biodegradable polymer film significantly effects on soil temperature, water conservation, and maize yield (Li et al., 2016). On the other hand, significantly lower grain yield was recorded in the weedy check (1.92 t ha^{-1}) as compared to other weeding treatments. This finding was supported by Karki et al., (2010).

Table 4. Effect of plant density and weed management practices on grain yield and stover yield of winter maize at NMRP, Rampur, Chitwan, Nepal, 2016

Treatments	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})
Plant density		
66666 plants ha^{-1}	3.7	4.0
83333 plants ha^{-1}	3.7	3.0
SEm (±)	0.2	0.6
LSD (=0.05)	NS	NS
CV, %	9.0	29.1
Weed management practices		
The weedy check	1.9^{d}	2.1^{c}
Weed-free	5.0^{a}	4.8^{b}
Two HW (30 and 60 DAS)	4.1^{bc}	2.4^{c}
Crop residue mulch (rice straw)	4.5^{ab}	5.3^{b}
Black plastic mulch	5.1^{a}	6.4^{a}
Atrazine + Pendimethalin	2.2^{d}	2.4^{c}
Atrazine + Pendimethalin + HW at 30 DAS	3.6^{c}	2.6
Atrazine + Pendimethalin +2,4-D 35 DAS	2.7^{d}	2.3^{c}
SEm (±)	0.3	0.3
LSD (=0.05)	0.7	0.8
CV, %	17.0	20.2
Grand mean	3.7	3.5

Note: Mean separated by DMRT and columns represented with the same letter (s) are non-significant at% level of significance. Note: PE (The pre-emergence), Post (Post-emergence); DAS (Days after sowing); HW (Hand weeding); W (Weed management practices)

CONCLUSION

Plant density did not significantly affect the weed dynamics viz. weed density (m^{-2}), weed dry weight (g m^{-2}), WCE, WI, grain yield (t ha^{-1}) and stover yield (t ha^{-1}) of winter maize. The weed dry weight and density were found significantly lower in black plastic mulch during the whole growing season of winter season. Higher weed control efficiency and lower weed index was also obtained in black plastic mulch treated plot. Similarly, higher grain yield and stover yield was also found in black plastic mulch than other weed management practices. Hence, black plastic mulch can be successfully deployed for effective weed management in winter maize to ensure better production.

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