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RESEARCH PAPER

Effect of straw mulching and herbicides on the weed density, dry matter accumulation of weeds and chlorophyll content in maize (*Zea mays* L.)

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Abstract : Field experiment was carried out during *Kharif* 2017 at Ludhiana and Gurdaspur to assess the weed density, DMA of weeds and chlorophyll content as influenced by straw mulching and herbicides in maize. Application of paddy straw mulch at 9.0 t ha^{-1} effectively controlled the density and DMA of grasses, broadleaf and sedges and resulted in significantly more leaf chlorophyll content in maize as compared to paddy straw mulch at 6.25 t ha^{-1} and no mulching. Pre-emergence application of atrazine at 1.0 kg ha^{-1} helped to manage density and DMA of grasses, broadleaf and sedges in comparison to atrazine at 0.8 kg ha^{-1} and unweeded check at 20 DAS. At 40 DAS of maize where maximum losses due to weeds occurred, the weeds were managed by post emergence application of tembotrione at 0.088 in combination with PSM 9.0 t ha^{-1} which reduced the density and DMA of grasses, broadleaf and sedges in comparison to atrazine at 0.8 and 1.0 kg ha^{-1} and unweeded check, but were equally effective as compared to tembotrione at 0.110 kg ha^{-1} and weed free treatment. The data showed that application of 9.0 t ha^{-1} mulch helped to reduce 20 per cent dose of atrazine and tembotrione for controlling weeds in maize.

Key Words : Atrazine, Maize, Straw mulching, Tembotrione, Weed density, Weed dry matter accumulation

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INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop grown in Punjab during the *Kharif* season. Among different biotic and abiotic factors responsible for reducing the crop yields, competition posed by weeds has been a major challenge in crop production as weeds cause severe reduction in yield by competing with crop plants for limited resources like light, space, nutrients and water. Weeds are the undesirable plants which affect the crop production, both in quality and quantity. Thus, weed control is a major challenge in maize production as weeds can curtail grain yield by 86 per cent (Bijanzadeh and Hossein, 2006). Globally, weed caused 10 per cent losses in agricultural production due to their competitive effect even regular control of weeds in most agricultural systems (Zimdahl, 2004). Severe infestation due to wider

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row spacing inflicts huge losses in yield, may be upto 52 per cent in maize (Walia *et al.*,2005). The extent of losses due to weeds, however, depends upon different weed species associated with crop, severity and critical period of weed infestation as determined by the density, biomass and spatial distribution of weeds in crop field, competitive ability of crop plants including the growth habit, canopy architecture and duration of crop, climatic conditions favouring the growth of weed plants and soil fertility status. Although, maize is a vigorous and tall growing crop, but it is susceptible to competition from weeds with losses more than 30 per cent commonly reported. Poor weed control leads to spread of weeds throughout the growing season and causes maize yield loss. Wilson and Westra (1991) observed that delay in controlling weeds till 6 weeks after planting, there was 16 to 28 per cent reduction in maize grain yield. Worldwide maize production is hampered upto 40 per cent by competition from weeds (Oerke and Dehne, 2004). Even small weeds during first week after emergence can reduce the grain yield substantially. Oerke (2005) reported that weeds caused 37 per cent loss potential which is followed by 18 per cent through insect pests, 16 per cent by fungal and bacterial pathogens and 2 per cent by viruses. These weed species varies with location, climatic conditions, cultural practices, crop rotation, soil management, weed control measures and inherent weed seed bank in the soil. Weed plants are blessed with many growth characteristics and adaptations which enable them to exploit successfully numerous ecological niches. Certain weeds by virtue of favourable adaptations like synchronized germination, shading effects by the crop at the time of establishment, quick response to available soil moisture and nutrients, adaptation to adverse soil and climatic conditions, herbicide resistance, morphological similarity and ready contamination with crop seeds make them associated with the specific crops. Weed flora changes with respect to location *viz.*, *Cyperus rotundus* and *Trianthema portulacastrum* were dominant weed species in spring maize at Hisar (Singh *et al.*, 1998) whereas at Orrisa, *Cynodon dactylon*, *Digitaria sanguinalis*, *Digitaria ciliaris*, *Leptochloa chinensis*, *Dactyloctenium aegyptium*, *Eleusine indica*, *Cyperus rotundus*, *Cyperus iria*, *Celosia argentea*, *Commelina benghalensis*, *Sida acuta* and *Aschynomene indica* were found dominant in rainfed maize (Rout and Satapathy, 1996). *Cyperus rotundus* as sedges was the most dominant weed in maize fields at Almora, Uttaranchal (Pandey *et al.*, 2001). However, at Pantnagar during *Kharif* season *Echinochloa colona*, *Trianthema portulacastrum*, *Cyperus rotundus* and *Eleusine indica* were the dominant weeds in maize fields (Singh and Prasad, 1994). Due to diverse weed flora, weeds become a major constraint in maize. The success of maize crop depends upon the weed control by using herbicides. However, herbicides should not be considered as replacement for other weed control measures but can be used in combination with these measures. The use of mulch has shown promising results for reducing weed pressure in maize (Bhatt and Khera, 2006; Sarkar and Singh, 2007 and Glab and Kulig, 2008). The combination of chemical and non- chemical approaches *i.e.* mulch will help in better control of weeds than use of any single approach in maize. This information is lacking in literature, so the present study was undertaken to gather information of controlling various weed species in maize with different straw mulch and herbicides levels.

Material and Methods

Field studies were carried out at two locations at Punjab Agricultural University, Ludhiana and Regional Research Station, Gurdaspur India during *Kharif* 2017. Soil at Ludhiana site was loamy sand in texture with pH of 7.5 and available N, P and K of 138.1, 17.2 and 179.1 kg ha^{-1}, respectively whereas at Gurdaspur site, the soil was sandy loam in texture with a pH of 7.4 and available N, P and K of 136.6, 18.9 and 195.3 kg ha^{-1}, respectively. Three straw mulch treatments: no mulch (NM), paddy straw mulch at 6.25 t ha^{-1} (PSM 6.25 t ha^{-1}), paddy straw mulch at 9.0 t ha^{-1} (PSM 9.0 t ha^{-1}) and six weed control treatments: atrazine at 1.0 kg ha^{-1} pre-emergence, atrazine at 0.8 kg ha^{-1} pre-emergence, tembotrione at 0.110 kg ha^{-1} at 20 DAS, tembotrione at 0.088 kg ha^{-1} at 20 DAS, weed free and unweeded check were investigated. Factorial Randomized Block Design was used with three replications. Hybrid PMH 1 was sown on June 22, 2017 at Ludhiana and June 6, 2017 at Gurdaspur with seed rate of 20 kg ha^{-1}. For controlling the weeds, herbicides Atrataf 50 WP (atrazine) as pre-emergence (within 2 days of sowing) and Laudis 420 SC (tembotrione) with activator at 1000 ml ha^{-1} as post-emergence (at 20 DAS) were applied as per treatments. The herbicides were applied with knapsack sprayer using a flat fan nozzle. Plant stand was recorded in each plot at 30 days after sowing (DAS) and at the time of harvesting the crop and expressed as number of plants per square metre. Chlorophyll content index was taken periodically at 30, 60 and 90 DAS with SPAD meter. Top third fully opened leaf was selected for recording this observation. Ten readings were taken from each plot with care so that mid-rib of leaf should not come under the eye of the instrument and the average value of chlorophyll content index was worked out. The weed density was recorded by randomly placing the quadrate (0.5 m ×0.5 m) at 20 and 40 DAS and categorized as grasses, broadleaf weeds and sedges. The weed density was reported as number m^{-2}. For dry matter accumulation at 20 and 40 days after sowing, the weed samples from two randomly selected spots in the quadrate (0.5m×0.5 m) were cut at the ground level and then dried in hot air oven at 60±2ºC till constant weight was obtained. The dry matter of weeds was expressed in g m^{-2}. The data on weed density and DMA of weeds were subjected to square root transformation $\sqrt{x+1}$ before statistical analysis. Data were statistically analyzed by factorial RBD using the SAS Proc GLM (SAS 9.3). The treatment comparisons were made at 5 per cent level of significance by using Duncun's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Plant stand:

Plant stand was recorded at Ludhiana and Gurdaspur after 30 days of sowing and at harvest and the data are given in Table 1. This parameter was recorded to observe the effect of different straw mulch and herbicide treatments on the plant stand which may ultimately influence the grain yield of the crop. The data showed that neither different levels of straw mulch nor herbicide treatments significantly influenced the plant stand both at 30 DAS and at harvest at both locations of Ludhiana and Gurdaspur, which indicated that both straw mulch and herbicide treatments were safe and did not show any adverse effect on the plant stand of maize.

Leaf chlorophyll content index:

Higher level of chlorophyll content in leaves indicates enhanced photosynthetic efficiency of the crop which influences the crop growth and yield. The data pertaining to leaf chlorophyll content in maize was recorded as Soil Plant Analysis Diagnosis (SPAD) values at 30, 40, 60 and 90 DAS and are presented in Table 2. At all the time intervals of 30, 40, 60 and 90 DAS, application of 9.0 t ha^{-1} mulch resulted in significantly more leaf chlorophyll content index values as compared to 6.25 t ha^{-1} and no mulch treatments at both locations of Ludhiana and Gurdaspur. Similarly, 6.25 t ha^{-1} mulch also resulted in significantly higher leaf chlorophyll content index values as compared to no mulch treatment at all the time intervals. This may be attributed to the better growth of plants and more availability of nutrients under straw mulching treatments as compared to no mulch treatment.

Leaf chlorophyll content index values (SPAD reading) were significantly influenced by weed control

Table 1: Effect of straw mulch and weed control treatments on plant stand of maize

Treatments	Plant stand (number m^{-2})			
	30 DAS		At harvest	
	Ludhiana	Gurdaspur	Ludhiana	Gurdaspur
Straw mulch application				
No mulch	8.32a	8.30a	7.96a	7.99a
PSM 6.25 t ha^{-1}	8.32a	8.24a	8.09a	8.02a
PSM 9.0 t ha^{-1}	8.31a	8.30a	8.09a	8.04a
Weed control treatments				
Atrazine at 1.0 kg ha^{-1}	8.32a	8.24a	8.11a	8.00a
Atrazine at 0.8 kg ha^{-1}	8.31a	8.30a	8.11a	7.97a
Tembotrione at 0.110 kg ha^{-1}	8.31a	8.30a	8.14a	8.04a
Tembotrione at 0.088 kg ha^{-1}	8.32a	8.30a	8.12a	8.09a
Weed free	8.33a	8.30a	8.14a	8.05a
Unweeded check	8.30a	8.24a	7.81a	7.93a

In a column, means followed by same letter do not vary significantly at 5% level by DMRT treatments at both the locations. At 30 DAS, maximum leaf chlorophyll content index values of 24.34 and 25.06 were recorded under weed free treatment at both the locations which were statistically at par with tembotrione at 0.088 kg ha^{-1}, atrazine at 1.0 kg ha^{-1} and tembotrione at 0.110 kg ha^{-1} treatments but was significantly higher than atrazine at 0.8 kg ha^{-1} and unweeded check, later two treatments also differed significantly with each other. At 40, 60 and 90 DAS, statistically similar SPAD values were obtained under weed free and tembotrione at both doses (0.088 and 0.110 kg ha^{-1}) treatments which were significantly higher than atrazine at both doses (0.8 and 1.0 kg ha^{-1}) and unweeded check at both the locations. However, minimum values of leaf chlorophyll content index were observed under unweeded check.

Total density of grasses, broadleaf weeds and sedges at 20 DAS:

The data on total weed density recorded at Ludhiana and Gurdaspur are presented in Table 3 which showed that total weed density was significantly influenced by straw mulch and weed control treatments. Application of straw mulch caused significant reduction in total weed density as compared to no mulch treatment. It was observed that at both the locations, application of 9.0 t ha^{-1} mulch recorded significantly less density of grasses,

Table 2: Effect of straw mulch and weed control treatments on leaf chlorophyll content index (SPAD values) in maize

Treatments	Leaf chlorophyll content index							
	30 DAS		40 DAS		60 DAS		90 DAS	
	Ludhiana	Gurdaspur	Ludhiana	Gurdaspur	Ludhiana	Gurdaspur	Ludhiana	Gurdaspur
Straw mulch application								
No mulch	21.39c	22.16c	24.82c	25.15c	32.59c	30.0c	35.37c	32.88c
PSM 6.25 t ha^{-1}	23.66b	24.23b	27.72b	28.11b	34.50b	32.03b	38.93b	36.54b
PSM 9.0 t ha^{-1}	24.85a	25.33a	29.67a	30.06a	36.47a	34.09a	41.60a	39.38a
Weed control treatments								
Atrazine at 1.0 kg ha^{-1}	23.83a	24.72a	27.57b	27.91b	35.57b	33.15b	38.94b	36.73b
Atrazine at 0.8 kg ha^{-1}	22.85b	23.04b	26.22c	26.55c	33.36c	29.94c	35.30c	33.14c
Tembotrione at 0.110 kg ha^{-1}	23.98a	24.73a	29.09a	29.38a	36.54a	34.67a	41.66a	39.95a
Tembotrione at 0.088 kg ha^{-1}	23.63a	24.51a	29.05a	29.43a	36.33a	34.74a	41.93a	39.83a
Weed free	24.34a	25.06a	29.04a	29.59a	37.07a	34.71a	42.22a	39.73a
Unweeded check	21.18c	21.39c	23.44d	23.78d	28.26d	25.05d	31.74d	28.22d

In a column, means followed by same letter do not vary significantly at 5% level by DMRT

Table 3: Effect of straw mulch and weed control treatments on total weed density in maize at 20 DAS

Treatments	Weed density (number m^{-2})							
	Ludhiana				Gurdaspur			
	Grasses	BLWs*	Sedges	Total	Grasses	BLWs*	Sedges	Total
Straw mulch application								
No mulch	12.82(211)c	3.60(15)c	12.37(191)c	18.06(417)c	4.43(23)c	4.27(24)c	13.40(212)c	14.73(259)c
PSM 6.25 t ha^{-1}	4.81(30)b	2.05(4)b	6.90(64)b	8.42(98)b	3.04(10)b	2.74(9)b	10.13(120)b	10.85(139)b
PSM 9.0 t ha^{-1}	3.49(15)a	1.69(2)a	5.46(40)a	6.45(57)a	2.34(5)a	2.06(4)a	9.19(99)a	9.58(108)a
Weed control treatments								
Atrazine at 1.0 kg ha^{-1}	3.27(21)b	1.41(1)b	3.21(19)b	4.37(41)b	2.45(5)b	1.16(0.5)b	10.62(116)b	10.87(122)b
Atrazine at 0.8 kg ha^{-1}	7.00(58)c	1.99(4)c	9.13(92)c	11.61(154)c	2.80(7)c	1.94(4)c	11.77(142)c	12.19(153)c
Tembotrione at 0.110 kg ha^{-1}	10.29(144)d	3.45(12)d	12.04(160)d	16.28(316)d	4.36(20)d	4.57(23)d	14.02(201)d	15.36(244)d
Tembotrione at 0.088 kg ha^{-1}	10.34(144)d	3.40(11)d	12.03(160)d	16.28(315)d	4.52(22)d	4.58(22)d	13.98(200)d	15.37(244)d
Weed free	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a
Unweeded check	10.35(145)d	3.43(13)d	12.04(160)d	16.31(318)d	4.50(22)d	4.87(26)d	14.06(202)d	15.54(250)d

Data were subjected to square root transformation $\sqrt{x+1}$. Original values are in parentheses

In a column, means followed by same letters do not vary significantly at 5% level by DMRT

BLWs*=Broad leaf weeds

broadleaf weeds and sedges as compared to 6.25 t ha^{-1} and no mulch treatments. Similarly, application of 6.25 t ha^{-1} mulch also resulted in significantly less density of grasses, broadleaf weeds and sedges as compared to no mulch treatment. Highest density of grasses, broadleaf weeds and sedges was recorded in no mulch treatment. Shah *et al.* (2014) also reported significantly lower density of weeds under mulch treatments in comparison to unweeded check.

Among herbicides, higher dose of atrazine effectively controlled total weeds in comparison to atrazine at lower dose and unweeded check, later two also differed significantly. However, the lowest total weed density was observed under the weed free treatment. Thus, the data indicated that application of atrazine at 1.0 kg ha^{-1} effectively controlled the weed flora at 20 DAS at both locations. Chopra and Angiras (2008) also reported that total weed density was significantly reduced with pre-emergence application of atrazine as compared to unweeded check.

Total density of grasses, broadleaf weeds and sedges at 40 DAS:

The interaction was significant with respect to the total density of grasses, broadleaf weeds and sedges (Table 4 and 5). The data showed that application of 9.0 t ha^{-1} mulch resulted in significantly lower density of grasses, broadleaf weeds and sedges as compared to 6.25 t ha^{-1} mulch and no mulch treatments irrespective to the herbicide treatments. Similarly, application of 6.25 t ha^{-1}mulch also recorded significantly lower density of total weeds than no mulch treatment at both the locations. Among the herbicide treatments, both at Ludhiana and Gurdaspur, lowest weed density was recorded under weed free treatment and highest under unweeded check as compared to all other weed control treatments, irrespective to straw mulch treatments. Tembotrione at both doses recorded statistically similar but comparatively lower density of grasses, broadleaf weeds and sedges as compared to atrazine at 1.0 kg ha^{-1} and atrazine at 0.8 kg ha^{-1} treatments irrespective of straw mulch treatments.

Table 4: Interactive effect of straw mulch and weed control treatments on weed density at 40 DAS (Ludhiana)

Treatments	Weed density (number m^{-2})								
	Grasses			BLWs*			Sedges		
	No mulch	PSM 6.25 t ha^{-1}	PSM 9.0 t ha^{-1}	No mulch	PSM 6.25 t ha^{-1}	PSM 9.0 t ha^{-1}	No mulch	PSM 6.25 t ha^{-1}	PSM 9.0 t ha^{-1}
Atrazine at 1.0 kg ha^{-1}	8.14(65)f	4.41(19)c	2.13(4)b	2.76(7)c	1.73(2)b	1.52(1)b	8.61(73)f	4.11(16)c	3.25(10)b
Atrazine at 0.8 kg ha^{-1}	10.50(109)g	5.71(32)d	2.54(6)b	4.31(18)d	2.43(5)c	1.99(3)b	13.48(181)h	9.16(82)f	6.73(44)e
Tembotrione at 0.110 kg ha^{-1}	5.13(26)c	2.74(7)b	1.00(0)a	1.90(3)b	1.61(2)b	1.00(0)a	5.26(27)d	3.67(13)c	3.00(8)b
Tembotrione at 0.088 kg ha^{-1}	5.24(27)c	2.55(6)b	1.00(0)a	1.99(3)b	1.61(2)b	1.00(0)a	5.35(28)d	3.72(13)c	2.75(7)b
Weed free	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a
Unweeded check	15.50(240)h	6.70(44)e	4.60(20)c	8.21(67)e	4.15(16)d	2.56(6)c	18.29(334)i	10.89(118)g	9.11(82)f

Data were subjected to square root transformation $\sqrt{x+1}$. Original values are in parentheses
Means followed by same letters do not vary significantly at 5% level by DMRT
BLWs*=Broad leaf weeds

Table 5: Interactive effect of straw mulch and weed control treatments on weed density at 40 DAS (Gurdaspur)

Treatments	Weed density (number m^{-2})								
	Grasses			BLWs*			Sedges		
	No mulch	PSM 6.25 t ha^{-1}	PSM 9.0 t ha^{-1}	No mulch	PSM 6.25 t ha^{-1}	PSM 9.0 t ha^{-1}	No mulch	PSM 6.25 t ha^{-1}	PSM 9.0 t ha^{-1}
Atrazine at 1.0 kg ha^{-1}	3.21(9)e	2.73(7)d	1.52(1)b	3.00(8)d	1.46(1)b	1.46(1)b	15.29(233)f	13.13(171)e	9.89(97)c
Atrazine at 0.8 kg ha^{-1}	4.86(23)f	3.36(11)e	2.24(4)c	3.60(12)e	2.14(4)c	1.52(2)b	15.91(253)f	13.60(184)e	10.36(107)c
Tembotrione at 0.110 kg ha^{-1}	1.90(3)c	1.52(1)b	1.00(0)a	1.90(3)b	1.46(1)b	1.00(0)a	11.59(133)d	10.29(105)c	7.37(53)b
Tembotrione at 0.088 kg ha^{-1}	1.90(3)c	1.52(1)b	1.00(0)a	1.90(3)b	1.52(1)b	1.00(0)a	11.61(134)d	10.18(103)c	7.39(54)b
Weed free	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a
Unweeded check	9.91(97)h	5.31(27)g	3.10(9)d	7.37(53)g	4.18(17)f	1.90(3)b	20.62(425)h	17.65(311)g	13.43(179)e

Data were subjected to square root transformation $\sqrt{x+1}$. Original valuesare in parentheses
Means followed by same letters do not vary significantly at 5% level by DMRT
BLWs*=Broad leaf weeds

Among the herbicide-mulch combinations, significantly lower density of grasses, broadleaf weeds and sedges was recorded with the application of tembotrione at 0.088 kg ha^{-1} and tembotrione at 0.110 kg ha^{-1} each in combination with 9.0 t ha^{-1} mulch and both these treatments were significantly better than all other herbicide combinations. The data further revealed that application of atrazine at lower dose in combination with straw mulch at 9.0 t ha^{-1} recorded significantly lower density of grasses, broadleaf weeds and sedges as obtained under atrazine at higher dose without mulch. Application of 9.0 t ha^{-1} mulch without any herbicide *i.e.* unweeded check resulted in significantly lower density of total weeds as obtained under atrazine at higher dose in combination with no mulch at both the locations.

Under no mulch treatments, atrazine at 1.0 kg ha^{-1} was more effective in reducing the density of grasses, broadleaf weeds and sedges than atrazine at 0.8 kg ha^{-1}. Tembotrione at lower dose (0.088 kg ha^{-1}) in combination with 6.25 t ha^{-1}mulch recorded significantly lower density of total weeds than tembotrione at 0.110 kg ha^{-1} without mulch, which indicates the beneficial effects of mulch application. Thus, the results showed that 20 per cent herbicide dose both in atrazine and tembotrione can be reduced with application of 9.0 t ha^{-1} mulch for controlling total weeds in maize. Pandey *et al.* (2002) reported that grass weeds offered maximum competition for crop growth and yield followed by broadleaf weeds and sedges.

Dry matter accumulation of weeds at 20 DAS:

At 20 DAS, the data on total dry matter accumulation (DMA) of weeds recorded at both the locations are presented in Table 6. The data showed that straw mulch treatments caused significant reduction in DMA of grasses, broadleaf weeds and sedges as compared to no mulch treatment. It was observed at Ludhiana and Gurdaspur that application of 9.0 t ha^{-1} mulch recorded significantly lowest weed DMA of grasses, broadleaf weeds and sedges as compared to 6.25 t ha^{-1} and no mulch treatments. Similarly, application of 6.25 t ha^{-1} mulch also recorded significantly lower weed DMA of grasses, broadleaf weeds and sedges as compared to no mulch treatment. Dutta *et al.* (2016) reported that straw mulch application helped to reduce the weed dry matter accumulation as compared to no mulch treatment.

Total weed DMA was also significantly affected by different weed control treatments at both the locations. The data showed that lowest DMA of weeds was recorded under weed free treatment. Among herbicides, atrazine at higher dose (1.0 kg ha^{-1}) recorded significantly less DMA of grasses, broadleaf weeds and sedges in comparison to its lower dose (0.8 kg ha^{-1}) and unweeded check at both the locations. Chopra and Angiras (2008); Woldetsadik and Chinawong (2005) and Salarzai (2001) also observed that weed DMA was effectively suppressed with atrazine over control. Similarly, atrazine at lower dose also recorded significantly less DMA of grasses, broadleaf weeds and

Table 6: Effect of straw mulch and weed control treatments on weed dry matter accumulation in maize at 20 DAS

Treatments	Weed dry matter accumulation (g m^{-2})							
	Ludhiana				Gurdaspur			
	Grasses	BLWs*	Sedges	Total	Grasses	BLWs*	Sedges	Total
Straw mulch application								
No mulch	3.01(10)c	1.55(2)c	4.08(19)c	5.06(31)c	1.98(3)c	1.51(2)c	5.46(33)c	5.81(38)c
PSM 6.25 t ha^{-1}	1.40(1)b	1.21(0.5)b	2.43(6)b	2.66(8)b	1.66(2)b	1.27(0.7)b	4.49(22)b	4.72(25)b
PSM 9.0 t ha^{-1}	1.23(0.6)a	1.11(0.2)a	2.03(4)a	2.18(5)a	1.42(1)a	1.11(0.2)a	4.06(18)a	4.20(19)a
Weed control treatments								
Atrazine at 1.0 kg ha^{-1}	1.29(0.8)b	1.07(0.1)b	1.52(2)b	1.69(3)b	1.46(1)b	1.08(0.1)b	4.72(23)b	4.84(24)b
Atrazine at 0.8 kg ha^{-1}	1.70(2)c	1.20(0.5)c	2.89(8)c	3.24(11)c	1.76(2)c	1.15(0.3)c	5.21(27)c	5.44(30)c
Tembotrione at 0.110 kg ha^{-1}	2.43(7)d	1.49(1)d	3.88(16)d	4.61(24)d	1.91(3)d	1.53(1)d	5.70(32)d	6.04(36)d
Tembotrione at 0.088 kg ha^{-1}	2.44(7)d	1.49(1)d	3.88(16)d	4.61(24)d	1.90(3)d	1.55(2)d	5.71(32)d	6.06(37)d
Weed free	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a
Unweeded check	2.44(7)d	1.50(1)d	3.92(16)d	4.64(24)d	2.09(4)d	1.57(2)d	5.67(32)d	6.09(38)d

Data were subjected to square root transformation $\sqrt{x+1}$. Original values are in Parentheses.
In a column, means followed by same letter do not vary significantly at 5% level by DMRT
BLWs*=Broad leaf weeds

sedges as compared to unweeded check. More DMA of weeds at 20 DAS under both doses of tembotrione was attributed to the fact that these treatments were applied after recording the weed data at 20 DAS.

Dry matter accumulation of weeds at 40 DAS:

Interaction between straw mulch and weed control treatments was significant with respect to total DMA of grasses, BLWs and sedges at 40 DAS at Ludhiana and Gurdaspur and are presented in Table 7 and 8. The data showed that application of 9.0 t ha^{-1} mulch produced significantly lower dry matter accumulation of grasses, BLWs and sedges as compared to 6.25 t ha^{-1} and no mulch treatments, irrespective of all the weed control treatments at both the locations. Similarly, application of 6.25 t ha^{-1} mulch also resulted in significantly less DMA of weeds in comparison to no mulch treatment. This showed the beneficial effect of straw mulching in controlling different weed flora and reducing the biomass as compared to no mulch treatment. Similar findings were reported by Dutta *et al.* (2016) on reduction of weed dry matter accumulation with straw mulching.

In weed control treatments, maximum total weed DMA of grasses, BLWs and sedges was recorded under unweeeded check and minimum under weed free, irrespective of straw mulch treatments. Barla *et al.* (2016) also reported that weed free treatment recorded significantly less dry matter accumulation of weeds as compared to weedy check at 30 and 60 days after sowing in maize crop. Among the herbicide treatments, significantly lower total weed DMA of grasses, BLWs and sedges was obtained under tembotrione at 0.088 kg ha^{-1} and tembotrione at 0.110 kg ha^{-1} as compared to atrazine at 1.0 kg ha^{-1} and atrazine at 0.8 kg ha^{-1} treatments, irrespective of straw mulch treatments. The data showed that tembotrione at 0.088 kg ha^{-1} and tembotrione at 0.110 kg ha^{-1} each in combination with 9.0 t ha^{-1} mulch recorded significantly lower DMA of total weeds as compared to all other herbicide combinations. Tembotrione at lower dose (0.088 kg

Table 7: Interactive effect of straw mulch and weed control treatments on weed dry matter accumulation in maize at 40 DAS (Ludhiana)

Treatments	Weed dry matter accumulation (g m^{-2})								
	Grasses			BLWs*			Sedges		
	No mulch	PSM 6.25 t ha^{-1}	PSM 9.0 t ha^{-1}	No mulch	PSM 6.25 t ha^{-1}	PSM 9.0 t ha^{-1}	No mulch	PSM 6.25 t ha^{-1}	PSM 9.0 t ha^{-1}
Atrazine at 1.0 kg ha^{-1}	7.58(57)i	3.74(13)d	3.70(11)d	2.57(6)de	2.33(5)d	1.81(2)bc	4.42(19)g	3.74(15)f	3.45(12)bc
Atrazine at 0.8 kg ha^{-1}	10.04(100)j	5.13(25)g	3.80(15)d	4.15(17)f	2.66(6)e	2.03(3)dc	6.77(45)I	4.48(19)g	3.73(15)f
Tembotrione at 0.110 kg ha^{-1}	4.53(20)ef	1.80(3)b	1.00(0)a	1.80(3)c	1.54(1)b	1.00(0)a	2.78(7)e	2.20(4)dc	1.66(1.8)b
Tembotrione at 0.088 kg ha^{-1}	4.76(22)fg	1.72(2)b	1.00(0)a	1.85(3)bc	1.53(2)b	1.00(0)a	2.92(8)e	2.20(4)dc	1.65(1.7)b
Weed free	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a
Unweeded check	13.47(181)k	5.80(33)h	4.43(19)e	8.53(72)g	4.42(19)f	2.70(6)e	8.94(79)j	5.57(30)h	4.42(19)g

Data were subjected to square root transformation $\sqrt{x+1}$. Original values are in parentheses
Means followed by same letter do not vary significantly at 5% level by DMRT
BLWs*=Broad leaf weeds

Table 8: Interactive effect of straw mulch and weed control treatments on weed dry matter accumulation in maize at 40 DAS (Gurdaspur)

Treatments	Weed dry matter accumulation (g m^{-2})								
	Grasses			BLWs*			Sedges		
	No mulch	PSM 6.25 t ha^{-1}	PSM 9.0 t ha^{-1}	No mulch	PSM 6.25 t ha^{-1}	PSM 9.0 t ha^{-1}	No mulch	PSM 6.25 t ha^{-1}	PSM 9.0 t ha^{-1}
Atrazine at 1.0kg ha^{-1}	2.91(8)g	2.06(3)e	1.65(2)d	1.70(1.9)c	1.51(1.3)b	1.11(0.3)a	8.07(64)fg	6.57(44)e	4.82(23)c
Atrazine at 0.8kg ha^{-1}	3.76(13)h	2.55(6)f	2.16(4)e	2.10(3.4)d	1.89(2.6)c	1.51(1.3)b	9.18(84)h	7.61(57)f	5.58(31)d
Tembotrione at 0.110 kg ha^{-1}	1.42(1)c	1.19(0.5)b	1.00(0)a	1.03(0.1)a	1.02(0.3)a	1.00(0)a	5.04(24)d	4.16(16)c	2.99(8)b
Tembotrione at 0.088 kg ha^{-1}	1.42(1)c	1.18(0.5)b	1.00(0)a	1.14(0.4)a	1.01(0.3)a	1.00(0)a	5..07(25)d	4.09(16)c	3.08(9)b
Weed free	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a	1.00(0)a
Unweeded check	9.12(84)i	3.68(13)h	2.89(7)g	5.62(32)f	3.17(10)e	1.83(2)c	12.74(162)i	8.53(72)gh	6.60(43)e

Data were subjected to square root transformation $\sqrt{x+1}$. Original values are in parentheses
Means followed by same letter do not vary significantly at 5% level by DMRT
BLWs*=Broad leaf weeds

ha^{-1}) in combination with 6.25 t ha^{-1} mulch resulted in significantly lower total weed DMA than tembotrione at 0.110 kg ha^{-1} without mulch treatment, further tembotrione at lower dose in combination with 9.0 t ha^{-1}mulchwas more effective in reducing total DMA of weeds as compared to tembotrione at 0.088 kg ha^{-1} in combination with 6.25 t ha^{-1}mulch. Tembotrione at lower dose in combination with 6.25 t ha^{-1} mulch resulted in statistically similar DMA of grasses, BLWs and sedges as obtained under tembotrione at higher dose (0.110 kg ha^{-1}) in combination with 6.25 t ha^{-1} mulch. Atrazine at lower dose (0.8 kg ha^{-1}) in combination with paddy straw mulch at 6.25 t ha^{-1} recorded comparatively lower total weed DMA as obtained under atrazine at higher dose (1.0 kg ha^{-1}) without mulch. Above findings indicated that straw mulch application at 9.0 t ha^{-1} helped to reduce 20 per cent dose of tembotrione and atrazine in maize.

It may be concluded that apply tembotrione at 0.088 kg ha^{-1} at 20 DAS in combination with mulch application at 9.0 t ha^{-1} for controlling weeds in maize.

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