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Weed management through rice straw mulching and herbicide use in maize

Ramandeep Kaur*, Charanjeet Kaur[1] and Tarundeep Kaur

Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab 141 004, India

[1] Regional Research Station, Gurdaspur, Punjab 143 521, India

**Email: ramandeepkaur201533@gmail.com*

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ABSTRACT

The field experiments were carried out at Ludhiana and Gurdaspur during *Kharif* 2017 to find out the influence of rice straw mulching and weed management treatments on weed density, weed dry matter and grain yield in maize. Use of rice straw mulch (PSM) at 9.00 and 6.25 t/ha recorded an average of 19.9 and 11.4% higher grain yield (5.91-6.21 and 5.46-5.81 t/ha), compared with no mulching (4.82-5.31 t/ha), respectively. The results showed that there was a reduction in average grain yield of 9.80 kg/ha with every increase in dry matter accumulation of weeds by 1.0 g/m^2. Post-emergence application of tembotrione (0.088 and 0.110 kg/ha) proved to be more effective than the pre-emergence application of atrazine (0.8 and 1.0 kg/ha) for controlling different weed species in maize. Both the doses of tembotrione (0.088 and 0.110 kg/ha) in combination with rice straw mulch at 9.00 t/ha displayed significantly lower weed growth and higher grain yield of maize in comparison to other treatments. The results showed that tembotrione at 0.088 kg/ha (PoE) in combination with PSM at 9.00 t/ha can be applied in maize for getting higher productivity, as this combination helps to reduce 20% dose of herbicide.

Maize (*Zea mays* L.) is adapted to diverse climatic conditions prevailing from tropical to temperate regions in India. The most suitable temperature for its maximum productivity is 20-27ºC although it can be grown at low temperature of 10ºC in a frost-free season. There is a lot of scope to increase the yield level due to its wider soil and climatic adaptability. Weed infestation is one of major factors that leads to reduction in maize yield due to wider row spacing and co-incidence of crop with rainy season, favouring severe crop-weed competition (Oerke and Dehne 2004). The infestation of weeds like *Acrachne racemosa, Brachiaria reptans* and *Commelina benghalensis* etc. are increasing day by day in maize growing belt of Punjab (Kaur *et al.* 2016).

Control of grasses, broad-leaved weeds (BLWs) and sedges remains a problem for the farmers, especially when too high or too low soil moisture hinders the intercultural operations along with the scarcity of labour during critical stages of weeding (Swetha *et al.* 2015). Moreover, manual weeding is time-consuming and cost-prohibitive. In absence of manual weeding, framers in irrigated areas rely on pre-emergence (PE) herbicides for controlling weeds (Rana *et al.* 2017) although it becomes ineffective many a times due to different constraints at farm level. Under these situations, the post-emergence (PoE) herbicides at about 40-45 days after sowing (DAS) appear to be an alternate option for minimizing the weed pressure at later period of crop growth (Kumar and Angadi 2014). But continuous and injudicious use of any herbicide may cause shift in weed flora, resistance in weeds and environment pollution. Rotational use of PE and PoE herbicides at temporal variation may help in avoiding these problems (Sahoo *et al.* 2016). In addition, different non-chemical measures like mulching can be explored since mulches exert positive effect on moisture, heat and air regime in the soil, thereby restricting moisture evaporation and weed growth (Choudhary and Kumar 2014). Mulching may also influence the effectiveness of herbicide use. In this view, the present study was carried out to study the combined efficacy of mulching and herbicide use toward weed management for improving growth and yield of maize.

The field experiments were conducted simultaneously at Punjab Agricultural University Ludhiana, and Regional Research Station, Gurdaspur in Punjab during *Kharif* season of 2017. The soil of two experimental sites at Ludhiana and Gurdaspur were of different textures (loamy sand and sandy loam) with pH values of 7.5 and7.4, and varying contents of available N (138.1 and 136.6kg/ha), available P (17.2 and 18.9kg/ha) and available K (179.1and 195.3 kg/ha), respectively. Three levels of mulching *viz*. no mulch, rice straw mulch (PSM) 6.25 and 9.00t/ha, and six different weed management treatments, *viz*. atrazine (Atrataf 50 WP) at 1.0 kg/ha (PE at 1 DAS), atrazine at 0.8 kg/ha (PE at 1 DAS), tembotrione at 0.110 kg/ha (PoE at 20 DAS), tembotrione at 0.088 kg/ha (PoE at 20 DAS), weed free and unweeded check were assigned in a factorial randomized block design with three replications at both the sites. As per treatment schedule, PSM was applied in between the lines immediately after the emergence of crop seedlings. The herbicides were also applied as per treatments with knap-sack sprayer fitted with flat-fan nozzle using spray volume of 500 and 375 L/ha for PE and PoE herbicides, respectively. Pre-sowing irrigation was applied to ensure adequate soil moisture at the time of sowing. At an optimum soil moisture condition, the field was prepared by giving two cultivations with tractor drawn cultivators, followed by (*fb*) planking. Maize variety '*PMH 1*' was sown by dibbling at the seed rate of 20 kg/ha and spacing of 60 × 20 cm on June 22 and June 06, 2017 at Ludhiana and Gurdaspur, respectively.The crop was fertilized with 125-60-30 kg N-P_2O_5- K_2O/ha, applying P_2O_5 and K_2O as basal and N in three splits (one-third basal, one-third at knee-high stage, and one-third nitrogen at pre-tasselling stage). First irrigation was given at 32 DAS, *fb* another one (Gurdaspur) to two irrigations (Ludhiana) in accordance with the crop requirement and rainfall receipt.

Floristic composition of weeds was recorded in unweeded check plots. The species-wise count of predominant weeds at 40 DAS was recorded by randomly placing the quadrate of 50 ×50 cm at two places, and the weed density was reported as number/m^2. For dry matter accumulation (DMA), the samples of all the species of different weed categories from two randomly selected spots in the quadrate of 50 ×50 cm were cut at the ground level at 40 DAS, and then dried in hot air oven at 60±2°C till the constant weight was obtained. The DMA of weeds was expressed in g/m^2. Maize plants were harvested from each net plot area (13.2 m^2) on September 29 and 15, 2017 at Ludhiana and Gurdaspur, respectively. The produce was kept in the field for sun-drying for 15 days and shelled with maize thresher, and the grain yield was adjusted to 15% moisture. Grain and stover yields along with yield attributes were recorded at harvest. Data on weed density and DMA were subjected to square root transformation $(\sqrt{x+1})$ before statistical analysis. All the data were statistically analyzed using the SAS Proc GLM (SAS 9.3). The treatment comparisons were made at 5% level of significance by using Duncan's Multiple Range Test.

Weed flora

The experimental plots at Ludhiana were infested with *Cyperus rotundus, C. compressus* (sedges), *Dactyloctenium aegyptium, Eleusine indica, Commelina benghalensis, Eragrostis tenella, Digitaria sanguinalis, Acrachne racemosa*, *Echinochloa colona* (grasses), *Trianthema portulacastrum, Portulaca oleracea, Digera arvensis* and *Mollugo nudicaulis* (BLWs) whereas Gurdaspur site had *C. rotundus* (sedge), *D. aegyptium, E. indica, C. benghalensis, Cynodon dactylon* (grasses), *T. portulacastrum, D. arvensis, Euphorbia hirta, Alternanthera philoxeroides, Phyllanthus niruri, Amaranthus viridis, Veronica agrestis* and *Conyza stricta* (BLWs).The weed species *Eragrostis tenella* and *Digitaria sanguinalis* were only observed at Ludhiana site.

Effect of density of predominant weeds

Among different weed species, there were three most dominant weeds *viz. Cyperus rotundus* (sedge), *Dactyloctenium aegyptium* (grass) and *Trianthema portulacastrum* (BLW) as recorded in accordance with the density at both the sites of experimentation.

***Cyperus rotundus*:** There was a significant effect on interaction between mulching and weed management treatments on the density of *C. rotundus* at both the sites (**Figure 1a-1b**). Application of PSM 6.25 and 9.00 t/ha resulted in significantly lower density (no./m^2) of *C. rotundus* (27 and 23 at Ludhiana, 146 and 82 at Gurdaspur, respectively) in comparison to no mulch (62 at Ludhiana and 196 at Gurdaspur), irrespective of weed management treatments. The lowest density of *C. rotundus* was recorded under weed free treatment (0 at both sites), whereas it was the highest under unweeded check (112 at Ludhiana and 305 at Gurdaspur) as compared to all other weed management treatments, irrespective of mulching treatments. Among the herbicide treatments, the lowest density of *C. rotundus* was observed under tembotrione at either of the doses (0.088 and 0.110 kg/ha) in combination with PSM 9.00 t/ha (7 and 3 at Ludhiana, 54 and 53 at Gurdaspur, respectively), and both the combinations were significantly better than the others at both the sites. Next in order were tembotrione at both the doses, applied in combination with PSM 6.25 t/ha (8 and 8 at Ludhiana, 103 and 105 at Gurdaspur), and atrazine 1.0 kg/ha in combination with PSM at 9.00 t/ha (10 at Ludhiana and 97 at Gurdaspur) for lowering the density of *C. rotundus*. At both the sites, it was observed that significantly less density of *C. rotundus* was recorded under atrazine at lower dose of 0.8 kg/ha in combination with PSM 9.00 t/ha in comparison to its higher dose without mulch. Similarly, tembotrione 0.088 kg/ha in combination with PSM 6.25 t/ha recorded significantly less density of *C. rotundus* as compared to tembotrione at 0.110 kg/ha without mulch at both the sites, thus indicating the advantage of PSM to control *C. rotundus*. Significantly higher density of *C. rotundus* was observed in unweeded check under no mulch treatment as compared to all other treatment combinations. Under no mulch treatment, the lowest density of *C. rotundus* was recorded under weed free treatment (0 and 0), *fb* tembotrione 0.110 kg/ha (17 and 133), tembotrione 0.088 kg/ha (20 and 134), atrazine 1.0 kg/ha (59 and 233), atrazine 0.8 kg/ha (92 and 253) and unweeded check(183 and 425) at Ludhiana and Gurdaspur, respectively. Pandey *et al.*(2001) also reported *C. rotundus* as the most dominant weed in maize fields.

Dactyloctenium aegyptium: At Ludhiana and Gurdaspur, the lowest density of *D. aegyptium* was recorded under weed free treatment and the highest under unweeded check as compared to all other weed management treatments, irrespective of mulching practices (**Figure 1c-1d**). Use of PSM 9.00 and 6.25 t/ha resulted in significantly lower density (no./m^2) of *D. aegyptium* (2 and 6 at Ludhiana, 1 and 3 at Gurdaspur, respectively)as compared to no mulching (31 at Ludhiana and 8 at Gurdaspur), irrespective of weed management treatments. Among the herbicide-mulch combinations, significantly lower density of *D. aegyptium* was recorded with both the doses of tembotrione in combination with PSM 9.00 t/ha(0 at both sites), and both the combinations were significantly better in comparison to the others. The data further revealed that atrazine at lower dose (0.8 kg/ha) in combination with PSM (either 6.25 or 9.00 t/ha)recorded significantly lower density of *D. aegyptium* than that obtained under higher dose (1.0 kg/ha) of the same herbicide applied without mulching. Sole use of PSM 9.00 t/ha without any herbicide application (unweeded check) resulted in significantly lower density of *D. aegyptium* (7 at Ludhiana and 3 at Gurdaspur) as obtained under atrazine at 1.0 kg/ha without mulch (33 at Ludhiana and 4 at Gurdaspur). In case of no mulch treatment, both tembotrione and atrazineat lower doses recorded comparatively more density of *D. aegyptium* (9, 49 at Ludhiana and 2, 7 at Gurdaspur, respectively) than their respective higher doses(6, 33 at Ludhiana and 1, 4 at Gurdaspur, respectively). The present study confirmed the findings of Yadav *et al.* (2018) who also observed that post-emergence application of tembotrione 120 g/ha along with surfactant (1000 ml/ha) was most effective against *D. aegyptium* as compared to atrazine 1.0 kg/ha and unweeded check. However, both the herbicides in combination with PSM 6.25 t/harecorded significantly lower density of *D. aegyptium* than their respective higher doses under no mulching. Thus, the results showed that tembotrione could be applied at either of the doses in combination with PSM 9.00 t/ha for minimizing the density of *D. aegyptium* in maize.

Trianthema portulacastrum: The interaction effect was significant with respect to the density of *T. portulacastrum* (**Figure 1e-1f**). At Ludhiana, use ofPSM (6.25 and 9.00t/ha) was found to significantly lower the density(no./m^2)of *T. portulacastrum* (0.5 and 0.4 at Ludhiana, 0.2 and 0 at Gurdaspur, respectively) as compared to no mulch treatment (5 at Ludhiana and 2 at Gurdaspur), irrespective of weed management treatments. The weed was effectively controlled under both the herbicides at both the doses, as well as weed free treatment, when imposed in combination with PSM (either 6.25 or 9.00 t/ha). All of these treatment combinations were significantly superior to the others. Use of atrazine at lower dose in combination with PSM 6.25 t/ha and sole application of PSM 9.00 t/ha without any herbicide (unweeded check) recorded statistically similar density of *T. portulacastrum* as obtained under atrazine at higher dose without mulching. Tembotrione at lower dose in combination with PSM 6.25 t/ha recorded significantly less weed density as compared to its higher dose without mulching. The highest density of *T. portulacastrum* was recorded in unweeded check under no mulch treatment. However, at Gurdaspur, all the combinations of straw mulching and weed management treatments effectively controlled the density of *T. portulacastrum*, excepting the application of atrazine at both doses without mulch and unweeded check under no mulch and PSM (6.25 t/ha) treatments. Significantly higher density of *T. portulacastrum* was observed in unweeded check under no mulch treatment as compared to all other treatment combinations. Saeed *et al.* (2010) reported that *T. portulacastrum*, being a strong competitor of maize, caused substantial yield losses depending upon the intensity of infestation.

Effect on dry matter accumulation of weeds

The interaction effect between mulching and weed management treatments was significant with

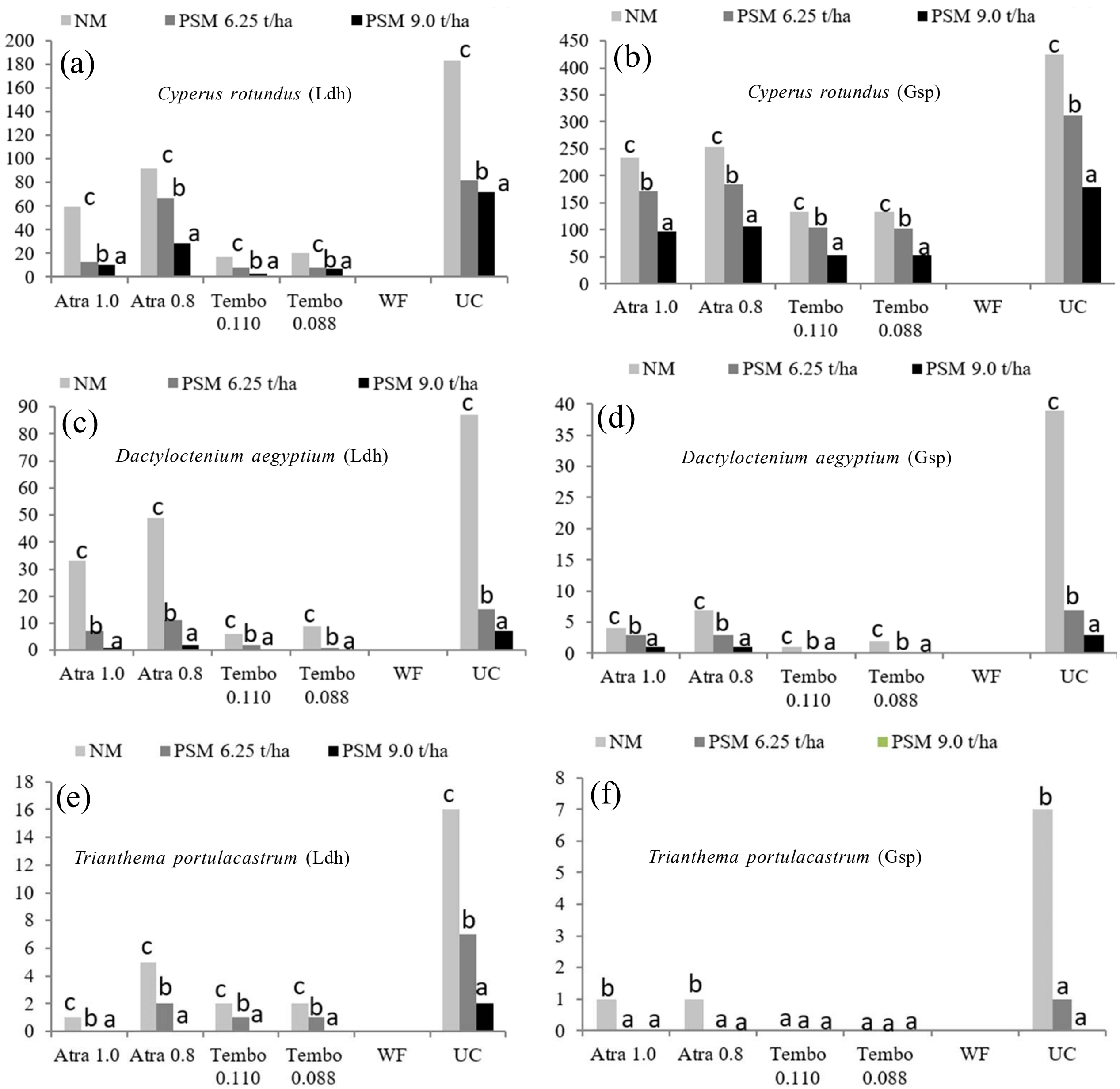

Figure 1(a-f). Density (no./m²) of different predominant weed species at 40 DAS as influenced by mulching and weed management treatments (Graphs with letters on bars represent the significant level of interaction. Different letters on grouped bars for each weed management treatment indicate significant difference between two bars. All herbicide doses are in kg/ha. Ldh, Ludhiana; Gsp, Gurdaspur; Atra, atrazine; Tembo, tembotrione; WF, Weed free; UC, Unweeded check)

respect to total DMA of weeds at Ludhiana and Gurdaspur **(Figure 2a-2b)**. Use of PSM at 9.00t/ha produced significantly lower DMA of weeds as compared to PSM 6.25 t/ha and no mulch treatments, irrespective of weed management treatments at both the sites. This showed the beneficial effect of PSM in controlling total weed biomasssince mulches did not provide necessary conditions for weed seed germination as well as weed growth (Patel *et al*. 2019). In case of weed management treatments, total weed DMA was the highestunder unweeded check, whereas it was the lowest under weed free, irrespective of mulching. Among the herbicide treatments, significantly lower value of total weed DMA was obtained under both the doses of tembotrione (0.088 and 0.110 kg/ha) as compared to atrazine (1.0 and 0.8 kg/ha), irrespective of mulching treatments. The results of present study are in consonance with the findings of Yadav *et al.* (2018) and Rana *et al.* (2017) who also observed that DMA of weeds in maize was significantly reduced with the application of tembotrione. Use of tembotrione (either

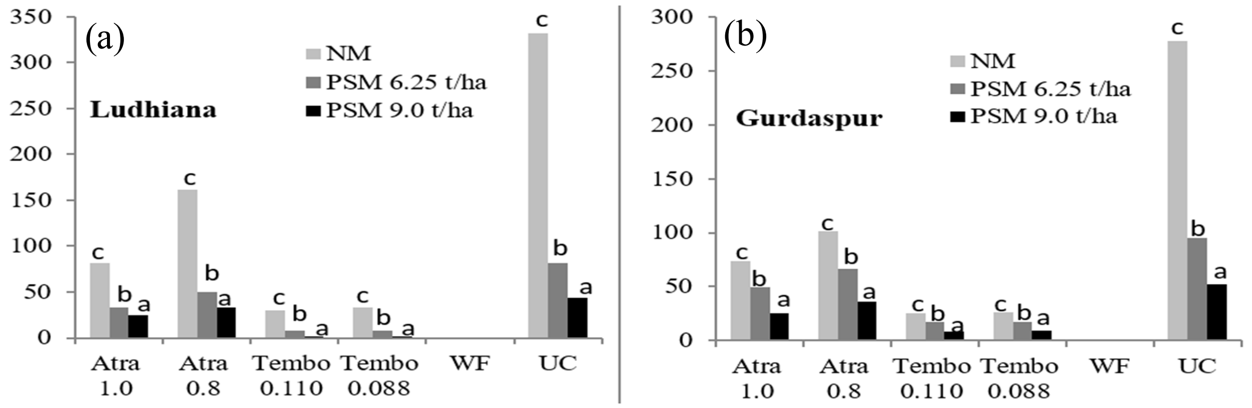

Figure2(a-b). Weed dry matter accumulation (g/m^2) at 40 DAS as influenced by mulching and weed management treatments. (Graphs with letters on bars represent the level of significant interaction. Different letters on grouped bars for each weed management treatment indicate significant difference between two bars. All herbicide doses are in kg/ha)

0.088or 0.110 kg/ha)in combination with PSM 9.00 t/ha recorded significantly lower DMA of total weeds than all other combinations. Next in order were the combinations of tembotrione (either 0.088 or 0.110 kg/ha)with PSM 6.25 t/ha. Tembotrione at lower dosein combination with PSM 6.25 t/haresulted in significantly lower total weed DMA than tembotrione applied at 0.110 kg/ha without mulching. Moreover, tembotrione at lower dose of 0.088 kg/ha in combination with PSM 9.00 t/ha was more effective than the same herbicide at either of its doses in combination with PSM 6.25 t/ha. Atrazine at lower dose in combination with PSM 6.25 t/ha recorded comparatively lower total weed DMA than the sole application of the same herbicide at higher dose without mulching. These findings indicated that PSM helped to reduce the dose of both the herbicides by 20%. Reduction in herbicide dose through PSM application was due to their physical presence on the soil surface that acted as barrier for light penetration required for weed seed germination, ultimately less weed population was observed that required less volume of water as well as herbicide use. Chauhan and Abugho (2013) also reported that combined use of mulch and herbicide can help in better management of weedsand maximizing the grain yield.

Yield and yield attributes

Grain yield, stover yield, no. of rows/cob, no. of grains/cob and 1,000-grain weight varied significant due to mulching practices (**Table 1**). Among the mulching treatments, PSM at 9.00 t/ha produced significantly higher maize grain yield in comparison to PSM 6.25 t/ha and no mulching. There were previous reports of significantly higher grain yield under mulching as compared to no mulch (Dutta *et al.* 2016, Uwah and Iwo 2011, Shah *et al.* 2014). Straw mulch significantly enhanced the grain yield by 14.4% as observed by Bahar (2013). Use of PSM at 6.25 and 9.00 t/ha significantly enhanced the grain yield by an average of 11.4% and 19.9% in comparison to no mulching, respectively, as also reflected similarly on different yield attributes (no. of rows/cob, no. of grains/cob, and 1000-grain weight) and stover yield. Enhanced stover yield under straw mulched treatments might be attributed to better soil surface conditions which were conductive for better crop growth. The lowest level of grain and stover yield along with yield attributes were recorded under no mulching at both the sites. The use of mulches possibly helped in better root growth that helped in better crop nutrition and higher productivity, compared with no mulching.

Weed management treatments significantly influenced the yield and yield attributes of maize at both the sites (**Table 1**). Weed free treatment produced maximum grain yield, which was statistically at par with tembotrione (0.088 and 0.110 kg/ha) and significantly superior to atrazine (0.8 and1.0 kg/ha) and unweeded check. Yadav *et al.* (2018), Rana *et al.* (2017) and Swetha*et al.* (2015) also reported higher grain yield with the application of tembotrione. Even the grain yield was significantly more in atrazine treatments than unweeded check, which was in consonance with the findings of Barla *et al.* (2016), Gul *et al.* (2016) and Mavunganidze *et al.* (2014). Higher values of yield attributes (no. of rows/cob, no. of grains/cob, and 1000-grain weight) along with grain and stover yields were also recorded under weed free treatment as well as both the doses of tembotrione in comparison to atrazine and unweeded check. Higher crop productivity under weed free and tembotrione was attributed to better weed control efficiency as well as improved crop

Table1. Yield and yield attributes as influenced by mulching and weed management treatments

Treatment	No. of rows/cob		No. of grains/cob		1,000-grain weight (g)		Grain yield (t/ha)		Stover yield (t/ha)	
	Ldh*	Gsp**	Ldh*	Gsp**	Ldh*	Gsp**	Ldh*	Gsp**	Ldh*	Gsp**
Mulching										
No mulch	13.3c	13.1c	408.8c	404.1c	263.8c	253.6c	5.31c	4.82c	11.25c	11.44c
PSM 6.25 t/ha	14.2b	14.1b	428.6b	422.6b	276.4b	266.6b	5.81b	5.46b	12.77b	13.07b
PSM 9.00 t/ha	14.5a	14.4a	441.4a	436.3a	282.2a	272.1a	6.22a	5.91a	13.85a	14.09a
Weed management										
Atrazine 1.0 kg/ha (PE)	14.0b	13.8b	420.0b	415.5b	273.6b	263.3b	5.62b	5.27b	12.69b	12.95b
Atrazine 0.8 kg/ha (PE)	13.5c	13.4c	409.8c	404.3c	268.7c	257.7c	5.33c	4.89c	11.78c	12.09c
Tembotrione 0.110 kg/ha (PoE)	14.6a	14.5a	445.1a	440.3a	279.4a	270.2a	6.24a	5.92a	13.69a	13.74a
Tembotrione 0.088 kg/ha (PoE)	14.4a	14.3a	443.9a	438.0a	278.9a	269.3a	6.23a	5.86a	13.61a	13.71a
Weed free	14.5a	14.4a	445.9a	440.9a	280.6a	271.4a	6.32a	5.97a	13.77a	13.89a
Unweeded check	12.9d	12.8d	393.0d	387.0d	263.7d	252.7d	4.94d	4.48d	10.22d	10.51d

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

growth as compared to other treatments. Application of atrazine at higher dose also recorded significantly higher yield and yield attributes in comparison to the same herbicide at lower dose and unweeded check. Similar results with atrazine were reported earlier by Sahoo *et al.* (2016) and Gul *et al.* (2016).The lowest level of yield and yield attributes were recorded in unweeded check at both the sites.

Relationship between grain yield and weed growth (weed data at 40 DAS)

The combination of mulching and herbicide treatments not only helped in reducing the weed pressure and increasing crop productivity, it also helped in reducing the dose requirement for herbicide use. Kumar and Angadi (2014) reported that the combined effect of mulching and atrazine application helped in improving the no. of rows/cob, no. of grains/cob and grain yield in maize as compared to unweeded check. At both the sites, the grain yield of maize displayed a negative linear relationship with weed density and DMA with respect to straw mulch and weed management treatments (**Figure 3-4**). Rana *et al.*(2017) reported that the grain yield of maize was negatively correlated with DMA of weeds.

In case of straw mulching, the weed density at 40 DAS was responsible for 96.6 to 99.5% variation in grain yield, whereas in case of weed management treatments it was responsible for 91.3 to 94.1% variation in grain yield. However, weed dry matter accumulation at 40 DAS was responsible for 95.8 to 97.6% variation in grain yield under straw mulching treatments, whereas it was responsible for 87.6 to 88.5% variation in grain yield under weed management treatments.

It was concluded that use of rice straw mulch 9.00 t/ha was more effective in terms of reducing the weed density and increasing the grain yield compared with no mulching. Application of tembotrione at 0.088 and 0.110 kg/ha (PoE) was superior to atrazine 0.8 and 1.0 kg/ha (PE)in reducing of density of different weed species and weed DMA. Tembotrione (0.088 or 0.110 kg/ha) in combination with PSM at 9.00t/ha was found to be the best combination for lowering the weed growth and increasing grain yield. Hence forgetting higher productivity, tembotrione at 0.088 kg/ha (PoE) in combination with PSM at 9.00 t/ha can be applied in maize, as this combination helps to reduce 20% dose of herbicide.

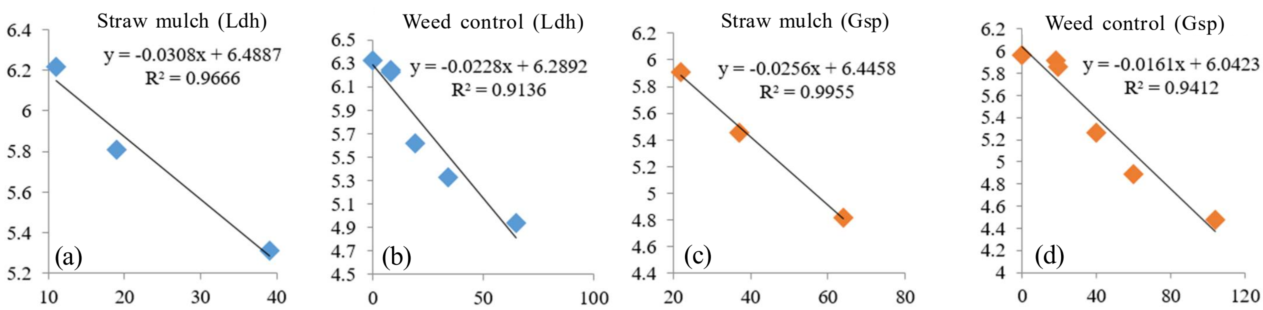

Figure 3(a-d). Relationship between grain yield (t/ha at y-axis)and weed density (no./m² at x-axis) in maize. The lines represent a linear model of regression.

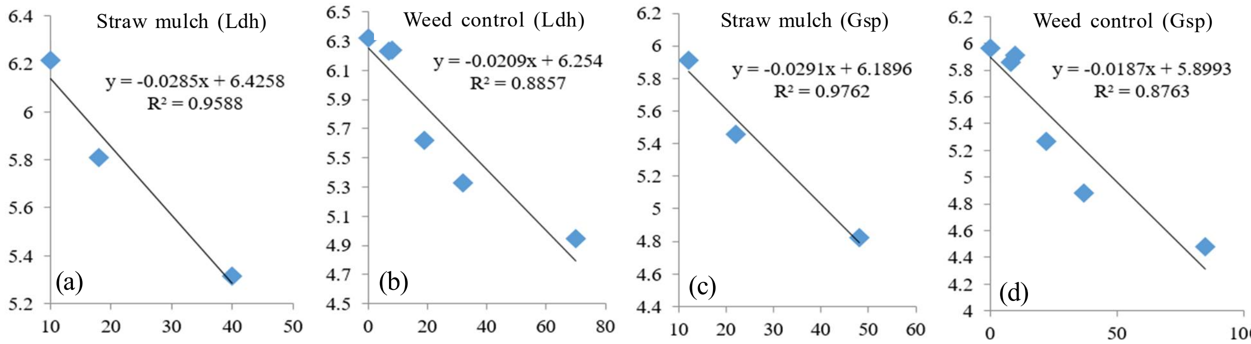

Figure 4(a-d). Relationship between grain yield (t/haat y-axis)andweed dry matter (g/m²at x-axis)in maize. The lines represent a linear model of regression

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