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Research Communication

Alleviation of herbicide load in maize (*Zea mays*) through paddy straw mulching and herbicide use

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ABSTRACT

A field experiment was conducted at 2 locations, Ludhiana and Gurdaspur, Punjab, during *kharif* 2017, to determine the effect of paddy straw mulching and herbicides on reduction of herbicide load in maize (*Zea mays* L.). Paddy straw mulch (PSM) at 9.0 t/ha resulted in highest weed-control efficiency, yield parameters, net returns, benefit : cost ratio and lowest weed index as compared to PSM 6.25 t/ha and no mulch treatments. Post-emergence application of tembotrione at 0.088 and 0.110 kg/ha resulted in highest WCE (96.3%) and was effective in lowering weed density and biomass as compared to atrazine at 0.8 and 1.0 kg/ha as pre-emergence. Tembotrione at 0.088 kg/ha in combination with paddy straw mulch (9.0 t/ha) recorded significantly lower weed density and dry-matter accumulation of all weed species and resulted in significantly higher grain yield, net returns and benefit : cost ratio which were statistically similar with tembotrione at 0.110 kg/ha in combination with paddy straw mulch 9.0 t/ha but significantly higher than all other combinations of straw mulch and herbicides. Therefore, for getting higher productivity and profitability from maize, apply tembotrione at 0.088 kg/ha as post-emergence in combination with paddy straw mulch 9.0 t/ha, as this herbicide-mulch combination helped in reduction of 20% dose of herbicide.

Key words: Atrazine, Economics, Maize, Straw mulch, Tembotrione

Maize is one of the most important cereal next to wheat and rice in the world. Owing to its low gluten content, its flour is considered a good diet for patients having cardiac problems. Being a versatile food crop of global importance, it also serves as a source of basic raw material for number of industrial products for food (25%), animal feed (12%), poultry feed (49%), starch (12%), brewery (1%) and seed (1%) as reported by Owla *et al.* (2015). Due to its sowing in rainy season as well as wider row spacing, it gets heavily infested with weeds. Use of herbicides provide effective control of weeds and are economical but their injudicious use has led to shift in weed flora, resistance in weeds and environment pollution. So to reduce dependence on herbicides, non-chemical measures of weed management are also gaining importance. Among non-chemical measures, mulching is an important agronomic practice for controlling the weeds in various crops. Rice–wheat is the major cropping system in Punjab and in this system paddy straw is usually burnt by farmers which leads to environmental pollution along with loss of essential plant nutrients. So, paddy straw can be used as mulch material for managing weeds in maize. It benefits in many ways like suppression of weeds, show positive effects on moisture, regulates soil temperature, increases soil porosity and water infiltration rate during intensive rain and controls runoff and erosion (Choudhary and Kumar, 2014). A single weed-control approach through herbicides may not be able to keep weeds below the threshold level and its effectiveness can be further enhanced by use of mulching. The knowledge regarding paddy straw mulch level and its combination with either pre-emergence or post-emergence herbicides is lacking in literature. Hence, an attempt was made to reduce herbicide load with combination of paddy straw mulch and herbicide use.

The experiment was carried out during the rainy season (*kharif*) 2017 as multi-location trial at Research Farm of the Punjab Agricultural University, Ludhiana and Research Farm of Regional Research Station, Gurdaspur. The experiment was laid out in a factorial randomized block design with 3 mulch treatments, i.e. no mulch (NM), paddy-straw mulch at 6.25 t/ha (PSM 6.25 t/ha) and paddy straw mulch

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at 9.0 t/ha (PSM 9.0 t/ha), and 6 weed-control treatments, viz. atrazine at 1.0 kg/ha pre-emergence, atrazine at 0.8 kg/ha pre-emergence, tembotrione at 0.110 kg/ha at 20 DAS, tembotrione at 0.088 kg/ha at 20 DAS, weed free and unweeded check. The soil at Ludhiana site was loamy sand in texture, having 138.1 kg/ha available N, 17.2 kg/ha available P and 179.1 kg/ha available K with 0.27 dS/m^2 electrical conductivity and *p*H value of 7.5, whereas at Gurdaspur it was sandy loam in texture with 136.6 kg/ha available N, 18.9 kg/ha available P and 195.3 kg/ha available K with 0.23 dS/m^2 electrical conductivity and *p*H value of 7.4. The field was prepared by giving 2 cultivations followed by planking and the sowing was done by dibbling method. Maize hybrid 'PMH 1′ was sown on 22 June 2017 at Ludhiana and on 6 June 2017 at Gurdaspur with seed rate of 20 kg/ha at row spacing of 60 cm and plant spacing of 20 cm. Phosphorus, potassium and zinc were applied uniformly before the planking operation through 60 kg/ha single superphosphate, 30 kg/ha muriate of potash and 25 kg/ha zinc sulphate. The crop was supplied with 125 kg/ha nitrogen through urea in 3 equal splits at sowing, 35 and 68 DAS. Paddy-straw mulch was applied immediately after the emergence of maize seedlings between the lines as per the treatments. For controlling the weeds, herbicides Atrataf 50 WP (atrazine) and Laudis 420 SC (tembotrione) with activator at 1,000 ml/ha were applied as pre-emergence (within 2 DAS) and post-emergence (at 20 DAS) herbicide, respectively, with knap-sack sprayer as per treatments. Weeds in the weed-control treatments were sampled from 2 quadrates of 0.5 m × 0.5 m. The crop was harvested on 29 September 2017 at Ludhiana and 15 September 2017 at Gurdaspur. Weed index and weed-control efficiency were calculated as per the following formulae:

$$WI = \frac{\text{Yield from weed free} - \text{Yield of particular treatment}}{\text{Yield from weed free}} \times 100$$

$$WCE = \frac{DMC - DMT}{DMC} \times 100$$

where DMC refers to dry matter of weeds in control (unweeded check) plot and DMT refers to dry matter of weeds in a treatment. The net returns were calculated by subtracting the total cost of cultivation for raising maize crop from the gross returns. Benefit : cost ratio (B : C) was derived from dividing the net returns by costs incurred to produce that net returns.

The predominant weed species observed at the experimental site of Ludhiana were: *Dactyloctenium aegyptium, Eleusine indica, Commelina benghalensis, Eragrostis tenella, Digitaria sanguinalis, Acrachne racemosa* and *Echinochloa colona* as grasses; *Trianthema portulacastrum, Portulaca oleracea, Digera arvensis* and *Mollugo nudicaulis* as broad-leaf weeds; and *Cyperus rotundus* and *Cyperus compressus* as sedges, whereas at Gurdaspur, the predominant weed species recorded were: *Dactyloctenium aegyptium, Eleusine indica, Commelina benghalensis, Cynodon dactylon* and *Eragrostis tenella* as grasses; *Trianthema portulacastrum, Digera arvensis, Euphorbia hirta, Alternanthera philoxeroides, Phyllanthus*

Table 1. Weed density and weed biomass at harvesting weed-control efficiency and weed index as influenced by straw mulch and weed-control treatments

Treatment	Weed density (m^2)		Weed biomass (g/m^2)		WCE (%)		Weed index (%)	
	Ludhiana	Gurdaspur	Ludhiana	Gurdaspur	Ludhiana	Gurdaspur	Ludhiana	Gurdaspur
Straw mulch								
No mulch	5.41 (39)	7.07 (64)	5.45 (40)	7.18 (48)	70.7	73.5	22.1	26.0
PSM 6.25 t/ha	3.93 (19)	5.50 (37)	3.90 (18)	5.57 (22)	90.5	88.8	14.8	16.2
PSM 9.0 t/ha	2.92 (11)	4.17 (22)	2.90 (10)	4.29 (12)	95.8	93.9	8.9	9.3
SEm±	0.06	0.11	0.06	0.16				
CD (*P*=0.05)	0.17	0.31	0.17	0.46				
Weed control								
Atrazine at 1.0 kg/ha	4.36 (19)	6.34 (40)	4.37 (19)	6.11 (22)	89.9	87.7	17.6	19.1
Atrazine at 0.8 kg/ha	5.78 (34)	7.71 (60)	5.57 (32)	7.59 (37)	78.8	81.4	21.9	25.0
Tembotrione at 0.110 kg/ha	2.75 (8)	4.20 (18)	2.75 (7)	4.07 (8)	96.2	96.3	8.6	9.1
Tembotrione at 0.088 kg/ha	2.88 (8)	4.31 (19)	2.78 (8)	4.14 (10)	96.2	96.4	8.7	9.9
Weed free	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	100.0	100.0	0.0	0.0
Unweeded check	7.75 (65)	9.91 (104)	8.02 (70)	11.16 (85)	0.0	0.0	27.6	31.2
SEm±	0.08	0.15	0.08	0.23				
CD (*P*=0.05)	0.24	0.44	0.24	0.66				

Figure in parentheses refer to original values and outside values subject to square root transformation ($\sqrt{x+0.5}$); WCE, weed-control efficiency.

niruri, Amaranthus viridis, Veronica agrestis and *Conyza stricta* as broadleaf weeds; and *Cyperus rotundus* as sedges. The weed flora were dominated by grassy weeds and sedges at both locations.

Application of PSM 9.0 t/ha recorded significantly lower weed density and weed biomass as compared to 6.25 t/ha and no mulch treatments (Table 1). Similarly, significantly less density and dry weight of weeds were observed with 6.25 t/ha mulch than no mulch treatment. Higher weed density and total weed dry weight were recorded under no mulch treatment. This study showed that PSM at 9.0 t/ha helped reduce density and biomass of weeds that lead to higher WCE and lower weed index (Table 1). Choudhary and Kumar (2014) and Dutta *et al.* (2016) also reported that mulch application helps suppress the weeds growth. Among herbicide treatments, tembotrione at 0.088 and 0.110 kg/ha recorded minimum weed density and dry weight that resulted in higher WCE and lower weed index as compared to atrazine at 1.0 and 0.8 kg/ha. All herbicide treatments performed better in comparison to unweeded check with respect to the weed index. Lower weed index under tembotrione at 0.088 and 0.110 kg/ha may be attributed to fewer losses due to weeds because they effectively controlled weeds as compared to the other weed control treatments. This showed that tembotrione at 0.088 kg/ha proved more beneficial than the other herbicide treatments for managing the weed flora in maize on economical basis. Further, atrazine at 1.0 kg/ha also recorded significantly less weed density and weed biomass, higher weed-control efficiency and lower weed index as compared to its lower dose and unweeded check. Mavunganidze *et al.* (2014), Sahoo *et al.* (2016), Stanzen *et al.* (2016) and Modak *et al.* (2019) also reported significantly less density and biomass of weeds and higher weed-control efficiency with atrazine application.

The number of rows/cob, number of grains/cob, grain yield and harvest index were significantly higher under at PSM 6.25 and 9.0 t/ha than to no mulch treatment (Table 2). Straw mulching and weed-control treatments did not significantly influence the number of cobs/plant. Weed-free treatment produced maximum number of grains/cob at Ludhiana and Gurdaspur, which was statistically at par with tembotrione at 0.110 kg/ha and tembotrione at 0.088 kg/ha but significantly higher atrazine at 1.0 kg/ha, atrazine at 0.8 kg/ha and unweeded check. Application of atrazine at higher dose also recorded significantly higher number of grains/cob in comparison to atrazine at lower dose and unweeded check. Higher yield attributes, shelling percentage and harvest index under the herbicide treatments were attributed to lower weed density and weed biomass that ultimately resulted in better growth and development of maize plants than to unweeded check. Similar findings

Table 2. Yield attributes, shelling percentage, harvest index, net returns and benefit : cost ratio in maize as influenced by straw mulch and weed-control treatments

Treatment	Number of cobs/ plant		Number of rows/cob		Number of grains /cob		Shelling (%)		Harvest index (%)		Net returns ($\times 10^3$ ₹/ha)		Benefit : cost ratio	
	Ldh	Gsp	Ldh	Gsp	Ldh	Gsp	Ldh	Gsp	Ldh	Gsp	Ldh	Gsp	Ldh	Gsp
Straw mulch														
No mulch	1.00	1.01	13.3	13.1	408.8	404.1	72.6	72.7	27.9	25.8	49.6	41.4	1.28	1.07
PSM 6.25 t/ha	1.06	1.02	14.2	14.1	428.6	422.6	74.0	74.2	28.5	26.3	57.2	51.1	1.42	1.27
PSM 9.0 t/ha	1.11	1.03	14.5	14.4	441.4	436.3	75.1	75.9	28.6	26.8	62.9	57.4	1.51	1.38
SEm±	0.06	0.02	0.1	0.1	2.8	2.2	1.3	1.1	0.2	0.2	0.5	0.4	0.02	0.01
CD (P=0.05)	NS	NS	0.2	0.2	8.9	6.8	NS	NS	0.5	0.5	1.3	1.2	0.04	0.03
Weed control														
Atrazine at 1.0 kg/ha	1.00	1.00	14.0	13.8	420.0	415.5	74.5	74.3	28.1	26.0	55.4	49.3	1.41	1.25
Atrazine at 0.8 kg/ha	1.00	1.00	13.5	13.4	409.8	404.3	73.1	73.7	27.9	25.4	50.6	43.3	1.30	1.14
Tembotrione at 0.110 kg/ha	1.11	1.02	14.6	14.5	445.1	440.3	75.7	76.2	28.7	27.0	65.1	59.2	1.65	1.49
Tembotrione at 0.088 kg/ha	1.11	1.04	14.4	14.3	443.9	438.0	75.5	75.9	28.8	26.9	65.2	58.7	1.66	1.49
Weed free	1.11	1.07	14.5	14.4	445.9	440.9	75.7	75.4	29.0	27.2	59.3	53.0	1.28	1.11
Unweeded check	1.00	1.00	12.9	12.8	393.0	387.0	68.9	70.0	27.4	24.9	43.7	36.4	1.13	0.94
SEm±	0.08	0.03	0.2	0.1	3.2	3.3	1.8	1.5	0.3	0.4	0.6	0.6	0.02	0.01
CD (P=0.05)	NS	NS	0.4	0.3	9.8	10.2	NS	NS	0.6	1.0	1.8	1.8	0.05	0.04

Ldh, Ludhiana; Gsp, Gurdaspur; PSM, paddy straw mulch.

Table 3. Interactive effect of straw mulch application and herbicide use on grain yield of maize

Treatment	Ludhiana			Gurdaspur		
	No mulch	PSM 6.25 t/ha	PSM 9.0 t/ha	No mulch	PSM 6.25 t/ha	PSM 9.0 t/ha
Atrazine at 1.0 kg/ha	5.31	5.65	5.91	4.86	5.28	5.66
Atrazine at 0.8 kg/ha	4.97	5.35	5.65	4.45	4.90	5.31
Tembotrione at 0.110 kg/ha	5.82	6.23	6.67	5.34	5.94	6.46
Tembotrione at 0.088 kg/ha	5.57	6.31	6.82	5.06	6.02	6.51
Weed free	5.83	6.31	6.82	5.32	6.07	6.51
Unweeded check	4.39	5.02	5.43	3.90	4.53	5.01
SEm±	S=0.03, H= 0.04, S×H=0.08			S=0.03, H= 0.04, S×H=0.07		
CD (*P*=0.05)	S=0.09, H= 0.13, S×H=0.22			S=0.09, H= 0.12, S×H=0.21		

PSM, Paddy straw mulch; S, straw mulch treatments; H, herbicide treatments; S × H, interaction between straw mulch and herbicide treatments.

were also reported by Kumar and Angadi (2014).

The interaction between straw mulch and weed-control treatments was significant with respect to grain yield (Table 3). On an average, application of PSM at 6.25 and 9.0 t/ha significantly enhanced the grain yield relative to no mulching by an average of 11.4 % and 19.9% respectively, which was attributed to higher weed-control efficiency and better plant growth under mulching. The data showed that tembotrione application at both doses (0.088 and 0.110 kg/ha) and weed free treatments in combination with 9.0 t/ha mulch resulted in statistically similar but significantly higher grain yield of maize than all the other treatments combinations, and these treatments were followed by tembotrione at 0.088 kg/ha, tembotrione at 0.110 kg/ha and weed free in combination with 6.25 t/ha mulch. It was interesting to note that tembotrione application at 0.088 kg/ha in combination with 6.25 or 9.0 t/ha mulch gave significantly the higher grain yield than tembotrione at 0.110 kg/ha without mulch, thus indicating that this combination helped in reduction of 20% herbicide dose. Kumar and Angadi (2014) and Rana *et al.* (2017) also reported that, mulch in combination with atrazine application enhanced the grain yield in maize.

The maximum net returns and benefit : cost ratio were recorded with the application of straw mulching at 9.0 t/ha which was significantly higher than straw mulch at 6.25 t/ha and no mulch treatment. The lowest net returns and benefit : cost ratio were observed under no mulch treatment at both the locations. Application of tembotrione at 0.088 and 0.110 kg/ha recorded statistically similar net returns and benefit : cost ratio and both these treatments were significantly better than weed-free, atrazine at 0.8 and 1.0 kg/ha and unweeded check. The higher net returns and benefit: cost ratio under these treatments were attributed to better weed-control efficiency and higher grain yield. Similar findings were reported by Bahar (2013) and Barla *et al* (2016).

It is concluded that application of PSM 9.0 t/ha and tembotrione at 0.088 kg/ha as post-emergence was found to be the best combination for controlling diverse weed flora and getting higher productivity and profitability from maize, as this combination helped in reduction of 20% herbicide dose.

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