Indian Journal of Agronomy **64** (4): 506—510 (December 2019)

Research Paper

Growth, nodulation and productivity of rainfed soybean (*Glycine max*) as influenced by mulching and anti-transpirants

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Received: July 2017; Revised accepted: November 2019

ABSTRACT

A field experiment was conducted during the rainy seasons (*kharif*) of 2012, 2013 and 2014 at the research farm of the Punjab Agricultural University, Ludhiana, Punjab, to study the effect of straw mulching and anti-transpirants on growth, nodulation and productivity of soybean [*Glycine max* (L.) Merr]. The experiment was laid out in factorial randomized complete, block design with 3 replications. The treatments included 2 mulching levels [wheat straw mulch @ 5 t/ha after sowing and control (no mulch)] and 5 anti-transpirants [5% magnesium carbonate ($MgCO_3$), 5% glycerol, 5% sodium carbonate (Na_2CO_3) in 2012 and during 2013 and 2014 sodium carbonate was 2%, potassium nitrate (KNO_3) 1% and control] during all the 3 years. Application of straw mulch @ 5 t/ha after sowing recorded the highest dry matter/plant, nodulation, plant height, pods/plant, straw yield and seed yield of soybean. Straw mulch recorded 17.6% higher seed yield and 22.6% higher rainfall use efficiency over no mulch. Straw mulching resulted in significantly higher gross (₹8,037) and net returns (3,037) as compared to the control (no mulch). Application of anti-transpirants had no significant effect on nodulation and seed yield of soybean. Application of potassium nitrate provided higher gross returns, net returns and benefit : cost ratio than the other anti-transpirants. However, use of anti-transpirants was not economical over the control. It is concluded that application of straw mulch @ 5 t/ha after sowing provides higher seed yield of soybean over no mulch.

***Key words*:** Anti-transpirants, Economics, Mulch, Nodulation, Soybean

Soybean is an important oilseed crop, grown mainly during *kharif* (rainy season). It plays an important role in agriculture for crop diversification, adding nitrogen to the soil during crop rotation (Singh and Shivakumar, 2010). In India, it was grown on an area of 10.60 million ha, with a production of 10.98 million tonnes and productivity of 1,036 kg/ha during 2017 (FAO, 2019). In India, area and production of soybean are dominated by Madhya Pradesh and Maharashtra, and the majority of area is rainfed. Soil moisture is one of the most limiting factors for crop production. It is lost as evaporation from soil surface and as transpiration from the plant surfaces. Reduction of transpiration and evaporation is needed for maintaining favourable water balance in the plants under limiting water conditions. Straw mulching helps in conserving the soil moisture and reduces soil temperature by modifying the hydrothermal regime (Singh *et al*., 2010; Aulakh *et al.,* 2012) and thereby, improves the emergence and growth of the crop.

In Punjab, 4.72 million tonnes of straw is generated every year. This includes 2.5 million tonnes of wheat straw and 2.2 million tonnes of paddy straw. Out of this, 95% of paddy straw and 25% of wheat straw are burnt each year (Kaur, 2017). This surplus crop residue can be used for mulching. Mulching provides suitable soil microclimate for soybean cultivation in the hot summer by controlling soil temperature and conserving soil moisture. The important constraint in soybean cultivation is the deficit of soil moisture during sowing and flowering to pod filling stage of crop. Optimum soil moisture is essential for obtaining high seed yield of soybean (Singh, 2010). In various regions of the world, water stress in crop plants can cause 50% yield reduction (Lisar *et al*., 2012). Plants under water stress can maintain favourable water balance through several ways like stomatal closure, leaf rolling, osmotic adjustments, reductions and consequently decreases in cellular expansion, alterations of various essential physiological and biochemical processes that can affect growth, productivity and quality (Farouk and Amany, 2012). Reduction in transpiration

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losses may help to alleviate adverse effects of water deficit and improve crop productivity under semi-arid conditions (Poljakoff-Mayber and Gale, 2012). Besides, foliar application of anti-transpirants protect the plants from moisture stress and improves the seed yield of soybean (Dass and Bhattacharyya, 2017). Considering the beneficial effect of mulching and paucity of information with regard to the effect of anti-transpirants on growth and productivity of soybean, the present investigation was undertaken to study the effect of straw mulch and anti-transpirants on growth, nodulation and productivity of soybean.

MATERIALS AND METHODS

A field experiment was conducted for 3 years from 2012 to 2014 during *kharif* (rainy season) at the research farm of the Punjab Agricultural University, Ludhiana (30° 54′ N, 75° 48′ E, altitude 247 m mean sea-level), India. The soil of the experimental site was low in organic carbon (0.29%), low in available nitrogen (145.1 kg/ha), high in available phosphorus (28.5 kg/ha) and medium in available potassium (153.5 kg/ha), with a *p*H of 7.9. A rainfall of 382.5 mm (26 rainy days), 732.4 mm (26 rainy days) and 418.7 mm (23 rainy days) was received in *kharif* season during 2012, 2013 and 2014, respectively during crop growth period.

Straw mulch of wheat @ 5 t/ha was applied after sowing and spraying of anti-transpirants was done at 15 days after flower initiation. Nutrients, viz. 30 kg nitrogen and 60 kg P_2O_5/ha were applied entirely as basal dose to the crop. The crop variety `SL 744` was sown on 7 June in 2012 and 6 June in 2013 and 2014 in rows, 45 cm apart using a seed rate of 75 kg/ha. Each subplot measured 5.0 m × 3.6 m in 2012 and 6.0 m × 3.6 m in 2013 and 2014. Weeds were controlled by spraying pendimethalin (Stomp 30 EC) @ 0.45 kg/ha as pre-emergence by using 500 litres of water. The crop was raised with the recommended package of practices (PAU, 2012) except irrigation.

Data on dry matter of plant was recorded from randomly selected 3 plants from each plot at 30 and 45 DAS during 2013 and 2014. The whole above-ground portion of the plants was taken and sun dried.

Observations for number and dry weight of nodules were recorded at 80 days after sowing. Five randomly selected plants were uprooted from each plot with their root system being intact. The roots were washed in running tap water and nodules carefully detached with forceps. The number of nodules were counted, nodules oven-dried at 60°C for 2 days and their dry weight was recorded. Data on number and dry weight of nodules were expressed on per plant basis.

Data on plant height and pods per plant were recorded at harvesting from randomly selected 5 plants from each plot. Biological yield and seed yield were recorded on the plot basis and then converted into kg/ha. Straw yield was obtained by subtracting seed yield from biological yield. The data on 100-seed weight were recorded after taking 100 randomly selected seeds. Harvest index was calculated by dividing seed yield by biological yield and multiplied by 100. Gross returns, net returns as well as benefit : cost (B : C) ratio were also worked out. Rainfall-use efficiency (RUE) was calculated by using the following formula:

$$\text{Rainfall-use efficiency (kg/ha-mm)} = \frac{\text{Grain yield (kg/ha)}}{\text{Rainfall received during crop growing period (mm)}}$$

Data were subjected to analysis of variance (ANOVA) in a factorial randomized complete block design (RBD) as

Table 1. Dry-matter and nodulation of soybean as influenced by mulch and anti-transpirants (pooled mean of 3 years)

Treatment	Dry matter/plant (g)*		Nodule number/plant	Nodule dry weight (mg/plant)
	30 DAS	45 DAS		
Mulch				
Mulch @ 5 t/ha	4.58	7.82	36.3	96.7
Without mulch (Control)	3.60	5.42	31.0	87.5
SEm±	0.11	0.23	1.1	1.6
CD (*P*=0.05)	0.32	0.70	3.4	4.7
Anti-transpirant				
Magnesium carbonate @ 5%	4.05	6.59	35.3	94.4
Glycerol @ 5%	4.20	6.60	34.2	91.7
Sodium carbonate	4.36	6.34	32.6	90.2
Potassium nitrate @ 1%	3.99	7.01	33.6	92.6
Control (Water spray)	3.85	6.55	32.3	91.5
SEm±	0.14	0.28	1.9	2.6
CD (*P*=0.05)	NS	NS	NS	NS

*Pooled mean of 2013 and 2014; DAS, days after sowing; NS, non-significant.

per the standard procedure.

RESULTS AND DISCUSSION

Growth parameters

Application of straw mulch @ 5 t/ha after sowing recorded significantly higher dry matter/plant than without mulch (control) at 30 and 45 DAS (Table 1). Higher dry matter/plant in straw mulching than without mulch (control) might be due to more soil moisture which helped in plant growth. Similarly, Dass and Bhattacharyya (2017) also reported that higher moisture regimes in mulched plots might have increased the crop growth. Moreover, application of surface mulch is known to modify the hydrothermal regimes of the soil surface by reducing the temperature (Aulakh *et al.,* 2012; Kumar *et al.,* 2013). Dry matter/plant at 30 and 45 DAS under different anti-transpirants, as expected, was similar (Table 1), as the anti-transpirants were applied at a later stage.

Nodulation

Nodulation was significantly influenced by the application of straw mulch @ 5 t/ha after sowing as compared to no mulch treatment (Table 1). Application of straw mulch recorded significantly higher number and dry weight of nodules/plant than without mulch. Straw mulching helps in lowering the soil temperature and conserving soil moisture by reducing water losses by evaporation (Aulakh *et al.,* 2012), thereby improving the micro-climate under mulching, which favoured greater nodulation (Siczek and Lipiec, 2011).

However, application of different anti-transpirants had non-significant effect on number and dry weight of nodules/plant (Table 1). Dass and Bhattacharyya (2017) also reported that anti-transpirants had no impact on nodulation.

Yield attributes, yield and rainfall-use efficiency

Application of straw mulch @ 5 t/ha after sowing recorded significantly higher plant height at harvesting, pods/plant, 100-seed weight, biological yield, straw yield and seed yield of soybean than without mulch (Table 2). Treatment of straw mulch recorded 17.6% higher seed yield over no mulch. Higher seed yield in mulching treatment could be owing to improved growth and yield attributes owing to role of straw mulching in maintaining the hydrothermal regime. Similarly, other researchers also reported that application of straw mulching improved emergence (Singh and Jolly, 2008; Singh, 2009), growth parameters and seed yield of soybean (Paliwal *et al.,* 2011; Jamir *et al*., 2016; Sanbagavalli *et al*., 2017). However, application of straw mulching did not affect the harvest index significantly (Table 2). Application of straw mulch @ 5 t/ha also increased the rainfall-use efficiency, which might be because of conservation of soil moisture by straw mulching. Straw mulching provided 22.6% higher rainfall use efficiency over without mulch (control).

Application of different anti-transpirants had non-significant effects on plant height, pods/plant, 100-seed weight, biological yield, straw yield and seed yield of soybean (Table 2). Similarly, application of anti-transpirants did not affect the harvest index significantly. However, application of sodium bicarbonate @ 5% showed phytotoxic effect on soybean leaves and reduced biological yield, straw and seed yield. Application of anti-transpirants had non-significant effect on rainfall-use efficiency. Non-

Table 2. Yield attributes, yield of soybean and rainfall-use efficiency as influenced by mulch and anti-transpirants (pooled mean of 3 years)

Treatment	Plant height at harvesting (cm)	Pods/ plant	100-seed weight (g)	Biological yield (t/ha)	Straw yield (t/ha)	Seed yield (t/ha)	Harvest index (%)	Rainfall-use efficiency (kg/ha-mm)
Mulch								
Mulch @ 5 t/ha	76.0	62.8	11.93	5.19	3.66	1.54	29.8	2.87
Without mulch (Control)	66.8	53.5	11.17	4.27	2.93	1.31	31.0	2.34
SEm±	0.9	1.2	0.07	0.08	0.07	0.02	0.5	0.05
CD (*P*=0.05)	2.7	3.5	0.21	0.22	0.21	0.06	NS	0.16
Anti-transpirant								
Magnesium carbonate @ 5%	72.0	59.5	11.58	4.69	3.27	1.41	30.4	2.64
Glycerol @ 5%	69.2	55.7	11.66	4.65	3.25	1.36	29.9	2.53
Sodium carbonate	71.6	56.5	11.59	4.54	3.17	1.38	30.6	2.47
Potassium nitrate @ 1%	70.3	59.4	11.22	4.80	3.29	1.47	31.4	2.72
Control (Water spray)	74.1	59.8	11.69	4.99	3.51	1.47	29.9	2.67
SEm±	1.5	1.9	0.12	0.12	0.11	0.03	0.8	0.06
CD (*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS, Non-significant.

Table 3. Economics of soybean as influenced by mulch and anti-transpirants (pooled mean of 3 years)

Treatment	Cost of cultivation ($\times 10^3$ ₹/ha)	Gross returns ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	Benefit: cost ratio
Mulch				
Mulch @ 5 t/ha	30.48	53.77	23.29	0.83
Without mulch (Control)	25.48	45.73	20.25	0.89
SEm±		0.71	0.71	0.04
CD (P=0.05)		2.13	2.13	NS
Anti-transpirant				
Magnesium carbonate @ 5%	41.25	50.94	8.33	0.20
Glycerol @ 5%	26.15	49.04	21.55	0.83
Sodium carbonate	25.17	49.82	23.28	0.93
Potassium nitrate @ 1%	24.35	53.05	27.23	1.12
Control (Water spray)	23.00	52.94	28.47	1.25
SEm±		1.12	1.12	0.05
CD (P=0.05)		NS	3.37	0.12

NS, Non-significant.

significant effects of anti-transpirants on yield attributes and yield (Table 2) could be due to good amount of rainfall received during the crop season, which masked the effect of treatments.

The interaction effect of mulches and anti-transpirants were non-significant for yield attributes and seed yield.

Economics

Application of straw mulch gave significantly higher gross returns and net returns as compared to control (no mulch) (Table 3). However, B : C ratio was non-significantly influenced by straw mulching. Straw mulch application provided ₹3,037/ha higher net returns over no mulch (control) treatment.

Application of potassium nitrate provided higher gross returns and net returns than other anti-transpirants. However, use of anti-transpirants was found not economical over the control. Magnesium carbonate provided substantially low net returns owing to high cost of chemical in this treatment.

It can be concluded that application of straw mulch @ 5 t/ha after sowing provided higher seed yield of soybean over no mulch whereas application of anti-transpirants was uneconomical.

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