

Effect of drip irrigation, fertigation and plastic mulching on growth and yield of soybean (*Glycine max*)

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Received: June 2020; Revised accepted: March 2021

ABSTRACT

A field experiment was conducted during the rainy season of (*kharij*) 2017 and 2018 at Ludhiana, Punjab, to study the effect of drip irrigation, fertigation and plastic mulching on productivity and quality of soybean [*Glycine max* (L.) Merr.]. Treatments comprised 3 levels of drip irrigation (1.0 × Etc, 0.8 × Etc and 0.6 × Etc) and 3 fertigation levels 50, 75 and 100% recommended dose of fertilizer (RDF) along with plastic mulch 25 micron, paddy straw mulch applied @ 6 t/ha and the control (no mulch and conventional furrow irrigation with recommended dose of fertilizer applied as basal broadcasting). Results showed that, under plastic mulch with drip irrigation 1.0 × Etc and 100% RDF applied through fertigation (T_9) recorded the maximum seed yield (2.31 t/ha), which was 57.1% higher than conventional furrow-irrigated crop with basal broadcasted fertilizers. Plastic mulched, drip irrigated 0.6 × Etc soybean yielded statistically at par or significantly higher than conventional bed planting furrow-irrigated crop which resulted in irrigation water saving of 32.7%. Soybean under plastic mulching enhanced the seed yield by 14.3% compared to bare soil (without mulch) drip-fertigated soybean.

Key words : Drip irrigation, Fertigation, Plastic mulching, Soybean, Yield

Soybean is a globally important crop for providing high-quality protein. It is estimated that soil-moisture stress cause 28–45% reductions in soybean yields (Hartman *et al.*, 2011). Soybean may be suitable alternative substitute for rice, keeping in view the increasing demand of vegetable oils of the country, almost 60% of which is met by imports. If appropriate technology is developed, we can attain high yield of soybean under moisture-stress conditions. Drip irrigation with fertigation is one such technologies which holds some promise. Drip irrigation not only helps to improve soil water and temperature conditions favourable for plant growth but also reduces the total water demands.

Below *et al.* (2016) observed significant increase in soybean yield by fertilizer applications through drip irrigation. Plastic mulch is another factor that creates favourable environment which helps promote the plant growth, increases water and nutrients uptake. Application of plastic mulching accelerates crop growth and augments crop yield by improving soil–water retention and controlling soil temperature (Kumar *et al.* 2015).

Therefore, plastic mulching has the potential to boost soybean growth yield by increasing available soil moisture and reducing the soil temperature in the root zone during hot summer months. In flat plastic mulching, a non-perforated plastic film covers a farmland and controls soil temperature and moisture regimes while protecting the soil from direct infiltration of rainfall on the beds.

Sekhon *et al.* (2005) reported that there was significant influence of mulching with wheat straw on soil temperature, growth and yield of soybean. Thus, present experiment was planned with the objective to study the effect of drip irrigation, fertigation and plastic mulching on growth and yield of soybean.

MATERIALS AND METHODS

A field experiment was carried out at the Research Farm, Department of Soil and Water Engineering, Punjab Agricultural University, Ludhiana, located at an altitude of 247 m, during the rainy (*kharij*) season of 2017 and 2018. The region is characterized by a subtropical and semi arid climate. Average annual rainfall is 700 mm of which about 70–80% is received during the monsoon season. The rainfall received during 2017 crop season was 364.8 mm, while during 2018 crop season it was 552.5 mm (Table 1).

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The soil of experimental field was sandy loam, with pH 8.3, low in available N (278 kg/ha) and organic matter (0.28%) and high in available P (38.2 kg/ha) and available K (185 kg/ha). The experiment was laid out in randomized block design with 3 replications with gross plot size of 16.2 m² and net plot size of 12.15 m². Of the 12 treatments T₁ to T₉ were sown after laying plastic mulch under bed planting system. The treatment details are: T₁, drip irrigation at 0.6 × Etc with 50% RDF through fertigation; T₂, drip irrigation at 0.6 × Etc with 75% RDF through fertigation; T₃, drip irrigation at 0.6 × Etc with 100% RDF through fertigation; T₄, drip irrigation at 0.8 × Etc with 50% RDF through fertigation; T₅, drip irrigation at 0.8 × Etc with 75% RDF through fertigation; T₆, drip irrigation at 0.8 × Etc with 100% RDF through fertigation; T₇, drip irrigation at 1.0 × Etc with 50% RDF through fertigation; T₈, Drip irrigation at 1.0 × Etc with 75% RDF through fertigation; T₉, drip irrigation at 1.0 × Etc with 100% RDF through fertigation. T₁₀, drip irrigation at 1.0 × Etc with 100 % RDF through fertigation with no mulch; T₁₁, drip irrigation at 1.0 × Etc with 100% RDF through fertigation + paddy straw mulch; and T₁₂, furrow irrigation with 100% RDF as conventional broadcast application (basal application). The recommended dose of fertilizer (RDF=100%) comprised 10 t/ha FYM, 31.25 kg N and 60 kg P₂O₅/ha. In the control plot with bed/furrow method of irrigation and manual application of fertilizer by broadcasting before sowing was considered as conventional/ control treatment (T₁₂). Raised beds were prepared using bed planter having top width of 37.5 cm and 30 cm wide furrow between 2 beds. The 16 mm drip lateral with inline emitters, spaced at 30 cm, was placed in the centre of each bed. The silver/ black plastic mulch 25 micron thickness and width 1.2 m was cut/ teared from centre with kite thread to make 2 pieces of equal width of 60 cm each, which was placed on the bed and buried on each side with soil. The holes in the sheet were made by using small pipe having diameter of 3.8 cm. The crop sown in paired rows, spaced at 20 cm in the centre of beds by dibbling. The soybean variety 'SL 958' was sown on 15 and 11 June 2017 and 2018 respectively. The seeds were inoculated with *Bradyrhizobium* culture of PAU, Ludhiana. Drip irrigation in different, treatments was given on every 3rd day (except rainy days) for whole season using 16 mm laterals with inline drippers and operated at a pressure of 1.5 kg/cm². Daily ET values for the crop season were calculated using Modified Penman method based on daily meteorological data collected from the PAU, Ludhiana. Fertigation was done, starting from 15 days after sowing (DAS), total fertilizer was applied in 8 equal splits at weekly interval up to 75 days after sowing (DAS). Nitrogen fertilizer was applied through urea by using venturi system. The data on plant height, leaf-area index were

recorded at periodic interval, while on nodule count and SPAD readings data were recorded at 45 and 90 DAS. Data on yield attributes and yield were recorded at the time of harvesting and threshing respectively. Irrigation water-use efficiency (IWUE) was calculated dividing soybean seed yield by the amount of irrigation water applied in mm. However, water use efficiency (WUE) was calculated dividing the soybean seed yield by total amount of water used in mm (irrigation water + effective rainfall).

RESULTS AND DISCUSSION

Growth parameters

The data on plant height at maturity showed that under plastic mulch treatments (T₁-T₉) the maximum plant height was recorded under T₉ which was statistically at par with T₆, T₈ and T₁₁ (Table 2). The control plot or farmers practice (T₁₂) recorded significantly lower plant height than all the drip-irrigated plots. These results confirm the findings of Kader *et al.* (2017) where it has been reported that soybean grown on plastic mulch-covered soil recorded significantly higher plant height than that grown on bare soil. At 45 DAS, maximum leaf-area index (LAI) among plastic mulch treatments was recorded under T₉ which was statistically at par with that recorded with T₆, T₈ and T₁₁ but significantly higher than T₁, T₂, T₃, T₄, T₅, T₇, T₁₀ and T₁₂. Similarly, at 90 DAS the maximum LAI was obtained under T₉ being statistically at par with T₆ and T₈ but significantly higher than rest of the treatments. Miyauchi *et al.* (2012) also reported that, soybean plants tend to increase LAI under mulching as compared to no mulch conditions during early stages of crop growth.

Soil plant analysis development (SPAD) values recorded at 45 DAS, were significantly influenced by different treatments. Under plastic mulch drip fertigation treatments (T₁-T₉), it was observed that maximum SPAD values were found under T₆ treatment which was significantly higher than T₁ and T₁₂ but statistically at par with rest of the treatments. The SPAD values recorded at 90 DAS in all the drip-fertigated plots with 75 or 100% RDF with plastic mulch or paddy straw mulch recorded significantly higher SPAD values than conventional furrow-bed irrigation system with broadcast application of fertilizer (T₁₂) and plastic mulch plots with 50% RDF application and irrigated at 0.6 × Etc or 0.8 × Etc or 1.0 × Etc irrigation levels (T₁, T₄ and T₇).

Nodules/plant of soybean plants supplied with 50% RDF under plastic mulch treatment showed that, increasing irrigation level from 0.6 × Etc (T₁) to 0.8 × Etc (T₄) resulted in significant increase in nodules/plant (Table 2). However, further increase in irrigation level to 1.0 × Etc (T₉) did not significantly increase the number of nodules/plant. With 100% RDF applied as fertigation, each higher level of ir-

rigation from 0.6 × Etc to 0.8 × Etc resulted in significant increase in nodules/plant. Further, it was observed that soybean grown on bare soil (no mulch) T₁₂ and T₁₀ recorded significantly higher nodule count than all plastic mulch treatments and T₁₁ (drip-fertigated with paddy straw mulch) was significantly superior to all the other treatments. Similar findings were reported by Mwamlima *et al.* (2019).

Yield attributes and yield

The maximum number of pods/plant was recorded under T₉ treatment, being statistically at par with T₆ and T₈ treatments and significantly higher number of pods/plant than all the other treatments. Significantly higher number of pods/plant under plastic mulching with drip fertigation may be attributed to better soil-moisture availability, relatively less weeds in vicinity of root zone resulting in better growth and development.

The 100-seed weight was not significantly influenced by different drip irrigation, fertigation or mulching treatments. Similarly, seeds/pod were not significantly influenced by different treatments. These results confirm the findings of

Kaur *et al.* (2020). Soybean sown after laying plastic mulch with drip irrigation applied at 1.0 × Etc and 100% RDF applied through fertigation (T₉) gave the maximum seed yield. Drip-irrigated soybean at 1.0 × Etc and 100% RDF applied through fertigation along with paddy straw mulch @ 6 t/ha (T₁₁) and drip fertigated (1.0 × Etc) without mulch (T₁₀) recorded significantly higher seed yield than conventional furrow-irrigated crop with basal and broadcast application of fertilizer. Overall, soybean under plastic mulching treatments recorded yield increase of 14.3% as compared to bare soil (without mulch) drip-fertigated soybean. Irmak *et al.* (2014) also reported similar results, where 15–18% increase in soybean yield under plastic film mulching was obtained as compared to the bare soil. The maximum stover yield was obtained under T₉ treatment. The harvest index was not influenced by different treatments. Kumar *et al.* (2015) and Candogan and Yazgan (2016) reported similar findings.

Quality parameters

The maximum protein content was recorded under T₁₁

Table 1. Weather parameters during crop growing season 2017 and 2018

Month	Actual rainfall (mm)		Normal rainfall (mm)	Air temperature (°C)					
	2017	2018		2017		2018		Normal	
				Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
June	96.0 (7)	11.9 (3)	84.0	36.8	26.2	37.6	26.0	38	26
July	112.0 (11)	256.1 (10)	215	34.6	27.5	33.5	27.2	34	26
August	131.4 (7)	165.6 (6)	187	33.9	26.7	33.3	26.5	33	26
September	25.4 (3)	85.4 (5)	105	33.7	24.0	33.2	24.2	33	23
October	0.0 (0)	16.4 (1)	11	33.2	18.5	31.3	19.0	32	17

Figures in parentheses indicate number of rainy days

Table 2. Growth, yield attributes and seed yield of soybean as influenced by irrigation, fertigation and mulching (pooled data of 2 years)

Treatment	Plant height (cm)	Leaf area index		SPAD reading		Nodule count (No.)	Pods/plant (No.)	100-seed wt (g)	Seeds/pod (No.)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index
		45 DAS	90 DAS	45 DAS	90 DAS							
T ₁	88.0	2.38	5.25	23.2	40.9	9.8	46.5	9.5	2.83	1.73	5.68	23.3
T ₂	92.5	2.72	5.75	26.6	45.3	11.8	49.3	9.5	2.90	1.88	6.54	22.3
T ₃	98.0	3.02	5.82	25.5	48.7	12.5	52.6	9.6	2.80	1.92	6.80	22.1
T ₄	90.0	2.78	5.71	27.3	41.2	12.5	48.5	9.7	2.80	1.90	6.35	23.0
T ₅	97.0	3.18	6.13	26.7	47.8	13.2	54.0	9.9	2.93	2.18	7.67	22.2
T ₆	100.6	3.43	6.35	27.5	48.8	15.5	56.8	9.9	2.87	2.23	7.77	22.6
T ₇	94.0	2.89	5.86	25.7	41.9	12.8	54.8	10.0	2.93	2.02	6.87	22.7
T ₈	101.1	3.35	6.30	27.1	47.2	15.3	57.8	10.1	2.90	2.24	7.33	23.4
T ₉	104.1	3.63	6.62	25.9	49.5	16.8	60.3	10.0	2.93	2.31	8.24	21.9
T ₁₀	97.2	2.97	5.22	25.3	43.5	19.2	49.1	9.4	2.83	1.79	7.30	19.6
T ₁₁	106.9	3.45	5.80	26.4	47.5	23.8	52.4	9.6	2.97	1.94	8.19	19.2
T ₁₂	78.0	2.90	5.09	23.3	40.0	19.7	46.1	9.2	2.70	1.47	5.69	20.6
SEM±	1.84	0.14	0.14	0.80	0.85	0.82	1.39	0.25	0.06	0.08	0.31	1.05
CD (P=0.05)	5.52	0.42	0.40	2.28	2.50	2.32	4.11	NS	NS	0.25	0.88	NS

Details of treatments are given under Materials and Methods

which was statistically at par with T₆, T₈, T₉ and T₁₀ and significantly higher than all the other treatments. It was observed that deficit irrigation treatments (T₁, T₂ and T₃) caused slight reduction in protein content in soybean (Table 3). The oil content obtained under T₁, T₂, T₃ and T₁₁ was significantly higher as compared to control. Maximum oil yield was observed under T₉ treatment. The minimum oil yield was recorded under T₁₂ treatment. Oil yield obtained under all the drip-fertigated treatments with mulch or without mulch recorded significantly higher values over control (T₁₂). It may be attributed to build up of microbial population which helped in better crop growth and seed yield (Singh *et al.*, 2020) and hence higher oil yield. The results corroborate the findings of Candogan and Yazgan (2016).

Water productivity

Under drip-irrigated plastic mulch, no mulch or paddy straw mulch, irrigation water applied varied from 28.6 to 40.9 cm averaged over 2 crop seasons. The water applied under conventional bed furrow-irrigated plot (control) was 42.5 cm when averaged over years (Table 3). The use of plastic mulch with drip irrigation applied at 0.6 × Etc resulted in irrigation water saving of 32.7% as compared to conventional bed furrow-irrigated plots.

The maximum irrigation water-use efficiency (IWUE) of 6.73 kg/ha-mm was obtained under T₃, while the minimum irrigation water-use efficiency obtained under T₁₂ was 3.46 kg/ha-mm. The higher IWUE under plastic mulch drip-irrigated plots may be attributed to reduced evaporation losses during early part of the growing season and relatively weed-free environment near the crop-root zone, resulting in reduced competition for soybean plants for wa-

ter and nutrients (Kumar *et al.*, 2015). The IWUE recorded under drip irrigation without mulch (T₁₀) and drip irrigation with paddy straw mulch (T₁₁) also recorded higher IWUE than the conventional system bed planting with furrow irrigation. Similar trend was observed for WUE which was higher under plastic mulch drip-irrigated plots followed by drip irrigation with paddy straw mulching, drip-irrigated without mulch followed by conventional bed furrow system of irrigation. Our results confirm the findings of Candogan and Yazgan (2016), that IWUE was higher under deficit drip-irrigated conditions, particularly when deficit irrigation was applied during early stages of crop growth.

Overall it was concluded that plastic mulch with drip irrigation (1.0 × Etc) and 100% recommended dose of fertilizer applied through fertigation (T₉) resulted in the maximum seed yield of 2.31 t/ha, which was 57.1% higher over conventional furrow-irrigated crop with basal broadcast fertilizers. Plastic mulch and drip-irrigated (0.6 × Etc) soybean yielded significantly higher than conventional bed planting furrow-irrigated crop which resulted in irrigation water saving of 32.7%. Soybean under plastic mulching enhanced the seed yield by 14.3% as compared to bare soil (without mulch) drip-fertigated soybean.

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Table 3. Protein content, oil content and oil yield of soybean as influenced by irrigation, fertigation and mulching (pooled data of 2 years)

Treatment	Protein content (%)	Oil content (%)	Oil yield (kg/ha)	Irrigation water applied (cm)	IWUE (kg/ha-mm)	WUE (kg/ha-mm)
T ₁	34.6	20.7	358.5	28.6	6.07	5.13
T ₂	36.4	21.2	397.3	28.6	6.58	5.55
T ₃	37.4	21.0	404.0	28.6	6.73	5.65
T ₄	36.0	18.8	357.9	34.8	5.46	4.75
T ₅	37.3	19.4	421.7	34.8	6.26	5.42
T ₆	39.0	19.4	433.0	34.8	6.42	5.57
T ₇	36.5	18.6	376.6	40.9	4.95	4.38
T ₈	37.9	19.4	434.9	40.9	5.48	4.86
T ₉	38.5	19.3	445.8	40.9	5.64	4.99
T ₁₀	37.8	19.2	342.6	40.9	4.36	3.44
T ₁₁	39.2	19.8	385.8	40.9	4.75	3.73
T ₁₂	34.7	18.9	277.9	42.5	3.46	2.61
SEm±	1.07	0.18	17.8	–	0.17	0.21
CD (P=0.05)	3.04	0.52	50.8	–	0.51	0.61

Details of treatments are given under Materials and Methods

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