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Research Communication

Productivity of soybean (*Glycine max*) under drip irrigation

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ABSTRACT

A field experiment was conducted at the research farm of Department of Soil and Water Engineering, Punjab Agricultural University, Ludhiana, and University Seed Farm, Ladhowal, Punjab, during the rainy (*kharif*) season of 2017, to study the effect of drip irrigation, fertigation and mulching on productivity of soybean [*Glycine max* (L) Merr.]. Among drip irrigation levels, seed yield increased significantly 14.2 and 11.8% with increasing drip irrigation level from 60% ETc to 80% ETc for Ludhiana and Ladhowal, respectively. Further increase in irrigation level up to 100% ETc increased the seed yield marginally by 3.5 and 4.6% for respective locations. With increasing fertigation level from 50% to 75% recommended dose of fertilizer (RDF), seed yield increased significantly to the tune of 9.2 and 9.4% for Ludhiana and Ladhowal respectively. However, further increase up to 100% RDF increased the seed yield by 4.8 and 5.3% for respective locations. Application of paddy straw mulch @ 6 tonnes/ha resulted in 13 and 9.8% increase in seed yield over no mulch. Mean of all combinations of drip irrigation, fertigation and mulching treatments recorded 12.3 and 19.2% increase in seed yield as compared to conventional furrow irrigation (control) for Ludhiana and Ladhowal respectively.

***Key words*:** Drip irrigation, Fertigation, Mulching, Soybean, Yield

The large-scale cultivation of rice (*Oryza sativa* L.) in Punjab, Haryana and Western Uttar Pradesh has increased the demand of irrigation water, causing a serious imbalance in its availability and consumption. In Punjab, the over-exploitation of ground water for last 2–3 decades has led to fall in the water table at 65 cm per year. In 66% area of central Punjab, watertable will go as deep as 21.37–51.51 m (70–160 feet) by 2023. Rice is a water-guzzling crop. Some alternative crop like soybean may substitute this crop, if appropriate technology is developed to attain high yield of soybean. Drip irrigation with fertigation is one such technology which holds some promise. In drip irrigation, water is applied through evenly spaced point sources or emitters and drip lines are placed either on the surface or buried in the soil root zone. Below *et al.* (2016) observed significant increase in soybean yield by fertilizer applications through drip irrigation. The yield and water productivity gains were owing to greater root proliferation, which was the result of moderation of soil temperature and water conservation with straw mulching (Arora *et al.,* 2011).

A field experiment was conducted during the rainy (*kharif*) season of 2017 at research farm, Department of Soil and Water Engineering, PAU, Ludhiana (30°54' N, 75°52' E and altitude 247 m) and University Seed Farm, Ladhowal (30^{o} 59 N and 75^{0} 44 E and altitude 229 m), Punjab, to study the effect of drip irrigation, fertigation and mulching on growth and yield of soybean. Soil of the experimental sites was sandy loam and loamy sand with slightly alkaline *p*H (8.6 and 8.8), low in organic carbon (0.18 and 0.20) and available N (257.5 and 252.5 kg/ha) and medium in available P (19.2 and 18.5 kg/ha) and K (165 and 166.5 kg/ha), at Ludhiana and Ladhowal respectively. The experiment was laid out in a randomized complete-block design with 3 replications. The treatments consisted of 3 levels of drip irrigation (60%, 80% and 100% ETc) and 3 fertigation levels 50, 75 and 100% recommended dose of fertilizers (RDF) and 2 mulch levels, i.e. no mulch and paddy straw mulch @ 6 tonne/ha. Paddy straw mulch was spread between the rows after sowing of soybean. The rainfall received during the cropping period of 2017 was 306.4 mm and 368 mm at Ludhiana and Ladhowal respectively. Rainfall received was above the normal in June but during later part of the crop season from July to September it was below normal rainfall. Maximum temperatures were below normal in month of June, but in

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later part of the crop season both minimum and maximum temperatures remain above the normal by 1–2°C. Soybean was sown on the beds, spaced 67.5 cm apart (37.5 top width, 30 cm furrow) by using wheat bed planter on 15 June and 22 June at Ludhiana and Ladhowal respectively. Two rows of soybean were sown on each bed. Fertigation was applied in 8 equal splits at weekly interval, starting 20 days after sowing (DAS) at Ludhiana and Ladhowal respectively. The recommended dose of nitrogen fertilizer was applied @ 15.6, 23.4 and 31.3 kg/ha for 50%, 75% and 100% RDF, respectively, at both the locations. The crop was sown after a pre-sowing *(rauni)* irrigation at both the locations. Drip irrigation was applied based on ET_o calculated by using modified Penman-Monteith equation as:

$$ET_O = \frac{0.408\Delta(R_n - G) + \gamma \dfrac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

Where

ET_o, reference evapo-transpiration [mm/day]; R_n, net radiation at the crop surface [MJ/m²/day]; G, soil heat flux density [MJ m/day]; T, mean daily air temperature at 2 m height [°C]; u_2, wind speed at 2 m height [m/s]; e_s, saturation vapor pressure [kPa]; e_a, actual vapour pressure [kPa]; e_s-e_a, saturation vapour pressure deficit [kPa]; D, slope vapour pressure curve [kPa/°C]; γ, psychrometric constant [kPa/°C].

The calculated ET_o was multiplied by appropriate value of crop coefficient (K_c) according to crop stage. The control plot applied with basal dose of fertilizers and surface furrow irrigation with a depth of 50 mm/irrigation at both the locations. In drip-irrigated plots, irrigations were applied at varied depth, depending on ETc values. The net plot of 8 m² was harvested to determine the yield. The statistical significance of the treatment effects on different parameters was inferred from the least significant difference (LSD) at 5% level of significance using analysis of variance for factorial randomized-complete block design.

Number of pods/plant is an important yield-contributing characters which is highly corelated to the final seed yield. Data showed that drip irrigation, mulching and fertigation levels significantly affected number of pods/plant. The maximum number of pods/plant was recorded in 100% ETc level of drip irrigation at both the locations. At Ludhiana, drip irrigation applied at 100% ETc resulted in significantly higher number of pods/plant than 80% ETc and 60% ETc. However, at Ladhowal both 100% and 80% ETc levels of drip irrigation recorded pods/plant statistically at par but significantly higher than 60% ETc (Table

Table 1. Effect of drip irrigation, fertigation and mulching on yield and yield attributes of soybean at Ludhiana and Ladhowal

Treatment	Pods/plant (no.)		Seeds/pod (no.)		100-seed weight (g)		Seed yield (t/ha)		Straw yield (t/ha)	
	I	II	I	II	I	II	I	II	I	II
Drip irrigation level										
60% ETc	55.8	40.6	2.49	2.36	9.5	8.9	1.48	1.36	2.37	2.49
80% ETc	58.0	43.3	2.54	2.47	9.6	9.1	1.69	1.52	2.86	2.85
100 ETc	59.5	44.1	2.68	2.51	9.8	9.1	1.75	1.59	3.09	3.04
SEm±	0.3	0.3	0.06	0.05	0.02	0.07	0.03	0.03	0.04	0.04
CD (P=0.05)	1.0	0.9	NS	NS	NS	NS	0.08	0.08	0.12	0.13
Mulching										
No mulch	57.0	41.9	2.56	2.42	9.6	9.1	1.54	1.42	2.73	2.74
Mulch	58.5	43.4	2.59	2.51	9.6	9.1	1.74	1.56	2.81	2.85
SEm±	0.27	0.23	0.01	0.01	0.17	0.00	0.02	0.02	0.03	0.04
CD (P=0.05)	0.8	0.7	NS	NS	NS	NS	0.06	0.07	NS	NS
Fertigation										
50% RDF	56.0	40.8	2.44	2.30	9.3	8.7	1.52	1.38	2.67	2.69
75% RDF	58.0	43.1	2.59	2.45	9.5	8.9	1.66	1.51	2.79	2.81
100% RDF	59.2	44.1	2.69	2.64	10.1	9.4	1.74	1.59	2.86	2.88
SEm±	0.3	0.3	0.48	0.31	0.13	0.22	0.03	0.03	0.04	0.04
CD (P=0.05)	1.0	0.9	NS	NS	NS	NS	0.08	0.08	0.12	0.13
Control	54.5	40.2	2.37	2.00	9.4	8.8	1.46	1.25	2.13	2.36
Treatments* vs control	57.8	42.7	2.57	2.45	9.6	9.0	1.64	1.49	2.45	2.79
SEm±	0.77	0.53	0.00	0.02	0.07	0.04	0.02	0.02	0.04	0.03
CD (P=0.05)	2.3	1.6	NS	NS	NS	NS	0.05	0.07	0.12	0.11

I, Ludhiana; II, Ladhowal; ETc Crop evapotranspiration; RDF, recommended dose of fertilizer

1). Palpriya (2012) reported significantly higher pods/plant in mungbean under drip irrigation level at 100% ETc as compared to 60% ETc. Application of paddy straw mulch significantly improved the number of pods/plant at both the locations. Among different fertigation levels, each higher level of fertigation resulted in significant improvement in number of pods/plant at both the locations. Number of seeds/pod and 100 seed-weights are an important yield attributes that influence final seed yield. More number of seeds/pod results in more number of seeds/plant, thus, increasing the seed yield per unit area. At both the locations, the number of seeds/pod and 100-seed weight were not significantly influenced by drip irrigation, fertigation and mulching. The findings are in close agreement with those of Miyauchi *et al.* (2012), where it was reported that drip irrigation with mulch had no significant effect on 100-seed weight of soybean. Drip irrigation applied at 100% ETc resulted in significantly higher seed yield (1.75 and 1.59 t/ha) than 80% ETc and 60% ETc at Ludhiana and Ladhowal respectively. Results showed that 20% reduction in irrigation water had no significant influence on seed yield. However, further reduction in irrigation water up to 40% (60% ETc) caused significant yield reduction to the tune of 15.4% as compared to 100% ETc level of drip irrigation at Ludhiana. Similarly, at Ladhowal, reduction in irrigation to 80% ETc and 60% ETc caused yield reduction of 4.4 and 14.5%, respectively. The highest seed yield obtained under irrigation applied at 100% ETc level resulted from cumulative effect of higher number of pods/plant, seeds/pod and 100 seeds-weight compared to 80 and 60% ETc. Kirnak *et al.* (2010) reported a drastic reduction in seed yield (76%) of soybean with decrease in irrigation from 100% of full irrigation to 25% of full irrigation applied by drip irrigation. Application of paddy straw mulch had significant effect on seed yield. Yadav and Singh (2014) also observed similar trend in seed yield with different irrigation schedules. The increase in yield might be owing to better aeration in the root zone under drip-irrigation method as compared to surface irrigation as reported by Kadam and Karthikeyan (2006). The increment in seed yield with mulch application was 13.0 and 9.9% at Ludhiana and Ladhowal, respectively, when compared with no-mulch application. Fertigation had significant influence on the seed yield at both the locations. The maximum seed yield of 1.74 t/ha was obtained with application of 100% RDF at Ludhiana, which reduced by 4.6 and 12.6% when fertilizer dose was reduced to 75 and 50% RDF, respectively. Similar trend was observed at Ladhowal, where it was observed that with the increase in fertilizer dose from 50 to 75% RDF the seed yield increased by 9.4%. With further increase in fertilizer dose to 100% RDF the yield increased by 5.3% as compared to 75% RDF. The overall mean of drip-fertigation treatments recorded significantly higher seed yield as compared to the control (furrow irrigation with fertilizer applied as basal dose at the time of sowing) at both the locations. Kumawat *et al.* (2000) reported similar trends in seed yield with different doses of nitrogen and observed highest yield when nitrogen was applied at 60 kg/ha which was statistically at par with 80 kg/ha nitrogen dose, results in saving of 20% of fertilizer under drip irrigation. Data revealed that each higher level of drip irrigation resulted in significant increase in straw yield. Application of drip irrigation at 100% ETc resulted in significantly higher straw yield than irrigation applied at 80% ETc and

Table 2. Effect of drip irrigation, fertigation and mulching on water expense (cm) and expense efficiency (kg/ha/cm) of soybean

Treatment	Irrigation depth (cm)		Soil profile contribution (cm)		Effective rainfall (cm)		Water expense (cm)		Water expense efficiency (kg/ha/cm)	
	I	II	I	II	I	II	I	II	I	II
Drip irrigation level										
60% ETc	17.7	13.3	2.4	1.6	11.3	13.9	31.4	28.8	44.9	47.1
80% ETc	23.6	17.7	2.2	1.4	8.9	11.9	34.7	31.0	47.6	49.2
100 ETc	29.5	22.1	2.1	1.1	4.6	8.4	36.2	31.6	49.9	50.2
Mulching										
No mulch	23.6	17.7	2.2	1.3	8.2	12	34.0	30.4	45.3	46.6
Mulch	23.6	17.7	2.3	1.4	8.2	12	34.1	30.5	49.6	51.1
Fertigation										
50% RDF	23.6	17.7	2.3	1.4	8.1	15	34.0	30.4	43.9	45.2
75% RDF	23.6	17.7	2.2	1.3	8.3	15	34.1	30.5	47.8	49.4
100% RDF	23.6	17.7	2.2	1.3	8.3	15	34.1	30.5	50.8	51.9
Control	25	25	1.6	0.7	15	15	41.6	40.7	28.2	29.6

I, Ludhiana; II, Ladhowal; ETc, Crop evapotranspiration; RDF, recommended dose of fertilizer

60% ETc. When irrigation was increased by 20% (80% ETc) it resulted in the increment of straw yield by 20.7 and 14.5% at Ludhiana and Ladhowal respectively. However, further increase up to 100% ETc increased the straw yield by 30.4 and 22.1% at respective locations. Different fertigation treatments showed that, with increase in fertilizer dose from 50% RDF to 75% RDF there was significant increase in straw yield; however, further increase in fertilizer dose up to 100% RDF did not result in significant increase in straw yield. But at Ladhowal straw yield was statistically at par between 50 and 75% fertigation level; however, further increase up to 100% RDF resulted in significant increase as compared to 50% RDF but it was statistically at par with 75% RDF application. Mulching showed non-significant effect on straw yield at Ludhiana and Ladhowal. Straw yield was significantly higher under drip-fertigation treatment compared to conventional furrow irrigation (control).

Water expense includes the water applied through irrigation and contribution of rainfall (Effective rainfall) and contribution from soil water profile used for meeting the crop-water requirement (Table 2). The data on water expense showed that at Ludhiana among drip-irrigation treatments, the maximum water expense (36.2 cm) was under 100% ETc which was reduced by 4.1 and 13.3% when irrigation was applied at 80% ETc and 60% ETc respectively. However, drip irrigation applied at 100% ETc level saved 14.9% water as compared to conventional furrow-irrigated crop. Similarly, at Ladhowal the maximum water expense of 31.6 cm was recorded under 100% ETc level of drip irrigation, which was reduced by 2.0 and 8.8% under 80 and 60% ETc respectively. Drip irrigation at 100% ETc level saved 28% irrigation water as compared to conventional furrow irrigated control at Ladhowal. Water-expense efficiency (WEE) (ratio of yield in kg/ha to the water expense in cm) was the highest, when irrigation applied at 100% ETc as compared to 60% ETc to the tune of 11.1 and 6.5% at Ludhiana and Ladhowal respectively. Mulch plot resulted 9.5 and 9.6% higher WEE over no mulch plot at Ludhiana and Ladhowal respectively. Application of 100% RDF resulted higher WEE over 75 by the increment of 5.9 and 5.1% at Ludhiana and Ladhowal, respectively. Further reduction in dose to 50% RDF caused 13.2 and 12.9% reduction in WEE at Ludhiana and Ladhowal, respectively. Conventional furrow irrigation system resulted in lower WEE as compared to drip-fertigated soybean at both locations.

From the above results, it can be concluded that drip irrigation resulted similar or slightly higher yield than conventional irrigation while consuming 25–29% less water at both the locations. Application of straw mulch @ 6 t/ha increased seed yield by 10–13%. Drip fertigation saved 20% fertilizers and increased the seed yield significantly.

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