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RESEARCH ARTICLE

Effect of irrigation scheduling and foliar fertilization on productivity, profitability and water use efficiency of soybean [*Glycine max* (L.) Merrill] under climatic variability of South Eastern Rajasthan

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SUMMARY

An experiment conducted during three consecutive years of *Kharif* (2013 to 2015) at Agricultural Research Station-Ummedganj, Agriculture University, Kota (Rajasthan) on soybean [*Glycine max* (L.) Merrill].The experiment consisted of twenty treatment combinations *viz*., four irrigation schedules (one irrigation at flowering, one irrigation at pod development, two irrigations at flowering and pod development and rainfed) and five foliar fertilization spray of N:P: K (5 g/lit. water) spray at 45, 60 and 75 DAS(17:44:00,19:19:19 ,17:44:00 ,19:19:19 and RDF) were under taken in split plot design with four replications. Three years pooled data showed that the maximum seed yield (1286 kg ha^{-1}) obtained under irrigation at flowering and pod development stage over irrigation at flowering stage and rainfed, but it was found at par with irrigation at pod development stagein soybean. The water use efficiency did not significantly influence under various irrigation schedules. Significantly higher net returns (Rs.19452/- ha^{-1}) and B: C ratio (1.84) were observed under irrigation at flowering and pod development stage, but it was found at par with one irrigation at pod development stage. Significantly higher seed yield (1333kg ha^{-1}) was recorded under foliar fertilization 19:19:19 (5 gm/lit) at 30, 45, 60 and 75 DAS, but it was found at par with 17:44:00 (5 gm/lit) at 30, 45, 60 and 75 DAS over rest of foliar fertilization. The water use efficiency was found maximum (23.46 kg/ha-cm) with foliar spray of 19:19:19 (5 gm/lit) at 30, 45, 60 and 75 DAS.The foliar fertilization of 19:19:19 (5 gm/lit) at 30, 45, 60 and 75 DAS gave significantly higher net return (Rs. 21081/- ha^{-1}) and B: C ratio (1.92), but it was found at par with foliar spray of 17:44:00 (5 gm/lit) at 30, 45, 60 and 75 DAS over rest of the treatments.

Key Words : Economics, Foliar spray, Irrigation schedules, Soybean, Water use efficiency

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Soybean (*Glycine max* (L.) Merrill) is an important food legume crop worldwide, providing vegetable protein for millions of people and ingredients for hundreds of food and non-food products. Soybean has paramount importance in human and animal nutrition, because it is a major source of edible vegetable oil and high protein feed as well as food in the world. Soybean is considered as miracle crop because it contains 38-42 per cent good quality protein, 23 per cent carbohydrates, 18-20 per cent oil, rich in poly unsaturated fatty acids, good amount of minerals and vitamins especially B-complex and tocopherols. It provides high amounts of phyto-chemicals and good quality dietary fibre which enables to protect human body against cancers and diabetes (Chouhan, 2007). Soybean has emerged as an important oilseed crop in India. On the national basis, soybean occupied an area of 12.09 million ha with production and productivity of 11.22 metric tonnes and 928 kg ha^{-1}, respectively (DAC and FW, 2019-20). Soybean is grown as a major oilseed crop mainly in south-eastern parts of Rajasthan during *Kharif* season. It covers 1.12 million ha with an annual production and productivity of 0.52 metric tonnes and 469 kg ha^{-1}, respectively in the state (DAC and FW, 2019-20).

Drought has been the major environmental constraint to plant survival and crop productivity in recent years (Boyer, 1982) and most climate change scenarios envision increasing aridity in many regions of the world in the years to come (Petit *et al.,* 1999). Given that the major agricultural use of water is for irrigation, a decrease in water supply will require more efficient water use, with deficit irrigation one way of maximizing water use efficiency and obtaining higher yields per unit of irrigation water applied. With deficit irrigation, crops are exposed to a degree of water stress during a particular period or throughout the growing season, with the expectation that any reduction in yield will be in significant when compared to the benefits gained by diverting the saved water to other crops (Kirda, 2002). Full irrigation is economically justifiable only when water is readily available and irrigation costs are low (James, 1993). In regions where there is a water deficit, irrigation can significantly increase soybean yields (Karam *et al*., 2005). However, soybean is produced in many arid, semi-arid and sub-humid regions where water resources are limited and deficit irrigation is a necessity. In such areas, new irrigation techniques that make use of deficient irrigation practices canresult in a more efficient use of water resources (Rosadi *et al*., 2005). The critical timing of irrigation for crops in humid and sub-humid areas may allow for a more judicious use of limited water supplies (Sweeney *et al.,* 2003). This study aimed to determine the yield and water use efficiency response of soybean to full and deficit irrigation applied at different growth stages under sub-humid climatic conditions.

Foliar application of nutrients constitutes one of the important milestones in the progress of agricultural production. It is gaining more importance in recent years due to availability of soluble fertilizers and is of great significance in rainfed areas and under changing climatic conditions. Nutrients applied through the fertilizers at the time of sowing are not fully utilized by the crop and are lost through leaching, fixation etc. and the crop may suffer from want of nutrients at the later stage. Foliar application of nutrients for increasing and exploiting genetic potential of the crop is considered as an efficient and economic method of supplementing the nutrient requirement of crop. Application of inorganic nutrients through foliage will enhance the nutrient availability due to quick absorption through leaves and in turn increases the crop productivity. Nutrients applied through foliage play a pivotal role in increasing the seed yield in pulses and oilseeds (Chandrasekhar and Bangarusamy, 2003). Hence, foliar nutrition is recognized as an important method of fertilization in modern agriculture. Polyfeed nutrient 19:19:19 fertilizer is a hundred per cent water soluble complete fertilizer containing nitrogen in three forms of namely, NO_3-N (45.0%), NH4-N (4.5%) and NH_2-N (10.5%) including water soluble phosphorus and potassium each containing 19% with low salt index. Therefore, it causes rapid and healthy crop growth and alleviate nutrients deficiencies quickly. It is made of high-quality ingredients providing balanced and complete nutrition to plants and virtually free of chloride, sodium and other detrimental elements. Potassium nitrate is a water soluble potassic fertilizer suitable for foliar application containing 44 and 32 % K_2O and NO_3-N, respectively (Yawalkar *et al.,*1996).

MATERIAL AND METHODS

An experiment was conducted during *Kharif* season 2013 to 2015 at Agricultural Research Station,

Ummedganj, Kota (Rajasthan), which is situated at South-Eastern part of Rajasthan. In Rajasthan, this region falls under Agro-climatic zone V B (Humid South eastern Plains) of Rajasthan. This zone possesses typical sub-tropical conditions with maximum and minimum temperatures ranged between 34.2°C to 38.0°C and 18.6°C to 24.0 °C during *Kharif*, season. The average amount of rainfall received during crop growing seasons was 1040 mm. The soil of experimental site was clay loam in texture, slightly saline in reaction. The experimental soil was medium in available nitrogen (264 kg ha^{-1}) and phosphorus (21.7 kg ha^{-1}) while high in potassium (388 kg ha^{-1}) and sufficient in DTPA extractable micronutrients with pH (7.61) and EC (0.52 dS m^{-1}). Source of nutrients applied were urea for nitrogen, DAP for phosphorus and mutate of potash for potassium.

The experiment consisted of twenty treatment combinations *viz.,* four irrigation schedules (one irrigation at flowering, one irrigation at pod development, two irrigations at flowering and pod development and rainfed) and five foliar fertilization spray of N:P: K (5 g/lit. water) spray at 45, 60 and 75 DAS (17:44:00,19:19:19 ,17:44:00 ,19:19:19 and RDF) were under taken in split plot design with four replications. Treatments were applied after making N:P:K fertilizer solution 5g in per litre water as per protocol. The data on seed yield, water use efficiency, net returns and B: C ratio were recorded as per standard procedures. The data were statistically analysed by adopting appropriate method of standard analysis of variance (Gomez and Gomez, 1984).

Irrigation water use efficiency was estimated as the ratio of seed yield (kg/ha) and irrigation water applied (mm) based on below formula :

WUE = Seed yield (kg/ha) /Irrigation water applied (mm)

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Effect of irrigation schedules on seed yield :

A perusal of data presented in Table 1showed that the application of increasing irrigation schedules significantly increases seed yield of soybean. The three years pooled data revealed that the maximum soybean seed yield (1286 kg ha^{-1}) was obtained under two irrigations at flowering and pod development stage as compared to one irrigation at flowering (1181 kg ha^{-1}) and rainfed (1178 kg ha^{-1}). However, it was found at par with one irrigation at pod development stage (1281 kg ha^{-1}) of soybean seed yield. The results are in agreement with those given by Payero *et al*. (2005) and Demirtas *et al.* (2010) who also found positive relationship between seasonal evapotran spiration and seed yield of soybean.

Table 1: Effect of irrigation schedule and foliar fertilization on yield and water use efficiency of soybean

Treatment	Seed yield (kg/ha)				WUE (kg/ ha-cm)			
	2013	2014	2015	Pooled	2013	2014	2015	Pooled
Irrigation schedule								
One irrigation at flowering	1162	1234	1148	1181	23.33	21.53	21.02	21.96
One irrigation at Pod development	1265	1340	1238	1281	22.68	21.17	20.43	21.42
Two irrigations at flowering and pod development	1268	1343	1246	1286	22.72	21.22	20.56	21.50
Rain fed (control)	1160	1232	1142	1178	23.30	21.50	20.92	21.91
S.E. ±	19.89	15.22	13.77	14.98	0.364	0.250	0.245	0.263
C.D. (P=0.05)	63.60	48.69	44.03	43.46	NS	NS	NS	NS
Foliar fertilization								
Spray of 17:44:00(5g/lit) at 45, 60 and 75 DAS	1236	1311	1203	1250	23.47	21.76	20.89	22.04
Spray of 19:19:19(5g/lit) at 45, 60 and 75 DAS	1244	1322	1216	1261	23.59	21.93	21.11	22.21
Spray of 17:44:00(5g/lit) at 30, 45, 60 and 75 DAS	1277	1365	1258	1300	24.17	22.63	21.84	22.88
Spray of 19:19:19(5g/lit) at 30, 45, 60 and 75 DAS	1309	1403	1286	1333	24.80	23.27	22.33	23.46
Control (RDF)	1003	1036	1006	1015	19.01	17.18	17.50	17.89
S.E. ±	13.83	16.66	17.87	14.83	0.265	0.276	0.311	0.261
C.D. (P=0.05)	39.36	47.42	50.86	41.45	0.755	0.786	0.884	0.729

NS= Non- significant

Several studies conducted for a wide range of environments have demonstrated that soybean yield increases with irrigation (Bajaj *et al*., 2008 and Gerçek *et al*., 2009). In the study period the yield of soybean was on average significantly higher in irrigated (4.559 t ha^{-1}) than in rainfed (3.739 t ha^{-1}) conditions. As precipitation cannot be predicted for long term in variable climate conditions, negative effect of irrigation may occur if it is done before a heavy rain, because in that case the soil may become over moist and the excess water may percolate into deep soil layers taking the nutrients with it (Pejic *et al*., 2009).

Effect of irrigation schedules on water use efficiency:

A reference to pooled data presented in Table 1 showed that the water use efficiency was recorded during experimentation in soybean. The water use efficiency of soybean crop did not significantly influence under different irrigation schedules. The results are in agreement with the finding of Howell (2001) emphasised that the best method to describe the role of irrigation has in water use efficiency in irrigated agriculture. Many researchers have evaluated water use efficiency in different ways significantly increase with irrigation schedules (Begg and Turner, 1976). Howell (1990) stressed that irrigation can be an effective means to improve water use efficiency through increasing crop.

Effect of irrigation schedules on economics :

A perusal of data presented in Table 2 showed that the application of irrigation schedulessignificantly increases monetary returns of soybean. Pooled data further revealed that the maximum net returns (Rs.19452/- ha^{-1} and B: C ratio 1.84) were observed under irrigation at flowering and pod development stage over one irrigation at flowering (Rs.16810/- ha^{-1} and B: C ratio 1.76) and rainfed (Rs.16713/- ha^{-1} and B: C ratio 1.75), but it was found at par with one irrigation at pod development stage (Rs.19303/- ha^{-1} and B: C ratio 1.83).

The results are in agreement with those given by Payero *et al*. (2005). The irrigation scheduling showed mark improvement in seed yield and thus gaining more profit in terms of net returns and benefit: cost ratio. The findings are in agreement with that of similarly, the monetary gains in terms of gross return and net return increased consistently and significantly with varying irrigation schedules (Demirtas *et al*., 2010).

Effect of foliar fertilization on seed yield :

A perusal of data presented in Table 1 showed that the application of N:P: Kfoliar fertilization significantly increases seed yield of soybean. Pooled data of three years revealed that the significantly higher seed yield of soybean (1333and 1300 kg ha^{-1}) was recorded under N:P: K foliar fertilization of 19:19:19 (5 gm/lit. water) and 17:44:00 (5 gm/lit. water) at 30, 45, 60 and 75 DAS, but it was found significantly superior over foliar

Table 2 : Effect of irrigation schedule and foliar fertilization on economics of soybean

Treatment	Net return				B:C ratio			
	2013	2014	2015	Pooled	2013	2014	2015	Pooled
Irrigation schedule								
One irrigation at flowering	13863	18553	18015	16810	1.62	1.83	1.81	1.76
One irrigation at Pod development	16271	21257	20379	19303	1.70	1.90	1.89	1.83
Two irrigations at flowering and pod development	16346	21366	20645	19452	1.71	1.93	1.90	1.84
Rain fed (control)	13809	18505	17826	16713	1.62	1.83	1.80	1.75
S.E. ±	616	502	482	491	0.03	0.02	0.02	0.02
C.D. (P=0.05)	1971	1606	1541	1424	0.09	0.07	0.07	0.06
Foliar fertilization								
Spray of 17:44:00(5g/lit) at 45, 60 and 75 DAS	15704	20641	19482	18609	1.69	1.91	1.86	1.82
Spray of 19:19:19(5g/lit) at 45, 60 and 75 DAS	15958	21016	19933	18969	1.71	1.93	1.88	1.84
Spray of 17:44:00(5g/lit) at 30, 45, 60 and 75 DAS	16703	22151	21133	19995	1.73	1.97	1.92	1.87
Spray of 19:19:19(5g/lit) at 30, 45, 60 and 75 DAS	17691	23413	22139	21081	1.77	2.02	1.97	1.92
Control (RDF)	9305	12382	13397	11694	1.43	1.57	1.61	1.54
S.E. ±	429	549	625	492	0.02	0.02	0.03	0.02
C.D. (P=0.05)	1220	1565	1780	1375	0.05	0.07	0.08	0.06

fertilization of 17:44:00 (5 gm/lit) at 45, 60 and 75 DAS (1250 kg ha^{-1}), 19:19:19 (5 gm/lit. water) at 45, 60 and 75 DAS (1261 kg ha^{-1})and control (1015 kg ha^{-1}). The higher dry matter accumulation by soybean crop was attributed to beneficial effect of nutrients particularly N, P and K in water soluble fertilizers in readily available form which were supplied through foliar spray. These nutrients were directly absorbed by plant either through cuticle or stomata and might have participated in photosynthesis activity in plant leaves leading to increased dry matter yield. Foliar spray resulted in timely supply of optimum quantity of nutrients to the plant and their subsequent absorption by soybean leaves resulting in better assimilation and translocation of nutrients. Further, phosphorus present in 19:19:19 fertilizer absorbed directly by the plant might have increased cell division and cell development leading to a greater number of branches. Thepresent findings corroborated the observations of Chohan and Raina (2010) in soybean and (Yadav and Choudhary, 2011) in cowpea.

Effect of foliar fertilization on water use efficiency :

A reference to pooled data presented in Table 1 showed that the water use efficiency of soybean crop was significantly increase with N:P:K foliar fertilization during experimentation. The water use efficiency of soybean crop was found maximum (23.46 kg/ha-cm) under foliar fertilization of 19:19:19 (5 gm/lit) at 30, 45, 60 and 75 DAS over foliar fertilization of 17:44:00 (5 gm/lit) at 45, 60 and 75 DAS (22.04 kg/ha-cm), 19:19:19 (5 gm/lit. water) at 45, 60 and 75 DAS (22.21 kg/ha-cm) and control (17.89 kg/ha-cm). However, it was found at par with foliar fertilization of 17:44:00 (5 gm/lit. water) at 30, 45, 60 and 75 DAS (22.88 kg/ha-cm). The irrigation water use efficiency depends on irrigation schedules. Irrigation scheduling provides water to the plants, which matches the crop evapotranspiration rate and provides optimum irrigation at critical growth stages, resulting in high water-use efficiency (Chohan and Raina, 2010). This increase in water saving might be due to the efficient use of water, which was applied to maintain the appropriate soil moisture along with the maximum yield obtained with the minimum quantity of water. Similar findings have also been reported byYadav and Choudhary (2011) in cowpea.

Effect of foliar fertilization on economics :

A perusal of data presented in Table 2 showed that the application of N:P: K foliar fertilization significantly increases monetary returns of soybean. Pooled data showed that the foliar fertilization of 19:19:19 (5 gm/lit) at 30, 45, 60 and 75 DAS gave significantly higher net return (Rs. 21081/- and B: C ratio 1.92), but it was found at par with foliar fertilization spray of 17:44:00 (5 gm/lit) at 30, 45, 60 and 75 DAS(Rs. 19995/- and B: C ratio 1.87) over foliar fertilization of 17:44:00 (5 gm/lit) at 45, 60 and 75 DAS (Rs. 18609/- and B: C ratio 1.82), 19:19:19 (5 gm/lit. water) at 45, 60 and 75 DAS (Rs. 18969/- and B: C ratio 1.84) and control (Rs. 11694/- and B: C ratio 1.54). Foliar fertilization with different water-soluble fertilizers in soybean increased the gross and net returns over control. Two foliar sprays of 1.0 % 19:19:19 was recorded higher net returns and B: C ratio followed by foliar spray of 2.0 % urea at 40 DAS and 1.0 % KNO_3 at 60 DAS. This might be due to higher economic yield obtained as a result of better utilization of nutrients through foliage. These results are in conformity with the findings of Chaurasia *et al*. (2005) and Singh (2013).

It is concluded that the application of irrigation schedule at irrigations at flowering and pod development stage gave significantly higher seed yield, water use efficiency andmonetary returnsin soybean. Application of N:P: K foliar fertilization19:19:19 (5 gm/lit. water) and 17:44:00 (5 gm/lit. water) at 30, 45, 60 and 75 DASalso recorded higher seed yield, water use efficiency and monetary return. Hence this irrigation schedule and foliar fertilization is proved as productive and beneficialto the farmers for obtaining higher returns in the zone V^{th} of Rajasthan.

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