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Research Paper

Techno economic feasibility of soybean based cropping systems under varying climates in Madhya Pradesh

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ABSTRACT

Building resilience to climate change through on farm management techniques such as crop diversification, and water management as supplemental irrigation is vital for sustainable agriculture. In the present study, soybean (*Glycine Max* L.) based cropping systems (sole crop, and intercropped with cotton or pigeon pea) through different combinations of cultivation practices (flatbed, raised bed) and irrigation levels (Rainfed, 66%ETc, 100%ETc and methods (drip, sprinkler) were studied in randomized block design with three replications during *kharif* season of 2019-20 and 2020-21. Plant growth parameters viz. plant height and dry weight were recorded maximum in rainfed soybean as sole crop, while the number of branches/plant were recorded maximum in sole soybean crop irrigated at 100%ETc. Grain yield (5.37 t/ha), and water productivity (0.47 kg/m^3) were maximum in soybean intercropped with cotton. Overall, cotton+soybean irrigated at 66% ETc can be adopted by farmers to achieve optimal productivity without significant yield penalty.

Keywords*:* Climate change, Crop evapotranspiration, Irrigation, Rainfed agriculture, Soybean.

Soybean (*Glycine Max L.*) Merrill is one of the most important oil seed crops grown in India during the *kharif* season. Soybean is looked upon not merely as a means to supply food for humans and animals, but also improves soil fertility by fixing atmospheric nitrogen (Jaiswal and Hugar 2011). Soybean contains 20% oil and 40% proteins along with a fair amount of lecithin and fat-soluble vitamins (Agarwal and Singh, 2014). In India, the soybean crop is cultivated over 12.09 Mha with a total production of about 11.22MT (Directorate of Economics and Statistics, 2022) of which Madhya Pradesh covers 53% of the cultivated area and delivers 60% of the total production (SOPA, 2021).

In recent years, area, production and productivity of soybean have shown a very erratic trend (SOPA, 2021). The trend may be an outcome of multiple factors like higher pest infestation, uneven distribution of rainfall, selection of cultivars for sowing and methods of sowing etc. (NFSM, 2018). Out of these, uneven distribution of rainfall is the result of uncertainties in monsoon viz. early onset of monsoon, late onset of monsoon, long dry spells during the monsoon (coincides with the crop growth period) (Kumar *et al.,* 2019) as it may nullify the advantages of higher precipitation on crop yield (Fishman, 2016). In rainfed regions like Bhopal, the water scarcity is much more economical rather than physical, whereas economical water scarcity is the unavailability of sufficient water during crop-critical growth periods. The longest period of several long dry spells is of crucial importance in planning agricultural activities and managing the associated water supply systems (Sharma, 1996). This irregular pattern of rainfall distribution along with the other abiotic climate changing factors likely to reduce world food levels by roughly 1.5% per decade without any adaptation and mitigation strategies (Lobell and Gourdji, 2012). Therefore, strategies are required to mitigate the adverse monsoonal influence on crop growth and yield. Intercropping with cotton or pigeon pea can make up for failure of soybean under rainfall variability. Therefore, in the present study, growth, yield and economics of soybean as sole crop and intercropped with pigeon pea/cotton were

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evaluated under rainfed and irrigated conditions for sustainable yield management in Madhya Pradesh.

MATERIALS AND METHODS

Experimental site

The present study was conducted at ICAR- Central Institute of Agricultural Engineering, Bhopal located between latitude 23°18′57.18′′N and 77°24′15.13′′E longitude at an altitude of 494 m above mean sea level in collaboration with International Centre for Agricultural Research in Dry Areas (ICARDA) during *kharif* season in 2019-20 and 2020-21. The field was uniform with a very slight slope (0.3-0.5%) from east to west direction. Soil of the experimental site was vertisols with heavy clay with clay content varying between 49.7 to 53.7%, silt content 28-34% and sand 12-18% with high organic matter content having field capacity of 28.5 to 31 % (Chandel *et.al*., 2022).

Experimental design

The experiment on soybean based cropping system with seven treatments was laid in randomized block design with three replications. The size of each experimental plot was 10.2 m × 6.5 m. The seven treatments consisted of soybean as sole crop, soybean + pigeon pea and soybean + cotton cropping system with different levels of irrigation. The varieties chosen for experimental purpose were soybean-JS-2034, cotton-Ajeet-5 and pigeon pea-TJT-501. The treatment details, rate of fertilizer application along with cultivation practices are mentioned in Table 1.

In all the treatments, according to crop, 100% of the recommended dose of NPK was applied. Irrigation scheduling was done on the basis of crop water requirement to meet the demand of crop evapotranspiration. Supplemental irrigation was given during longer dry spells (when the rainfall received was less than 35 mm in the preceding two weeks) on the basis of crop evapotranspiration (ETc) (Allen, 1998). Pearson's correlation coefficient was estimated between different weather variables such as maximum and minimum temperature, rainfall, relative humidity with soybean seed yield at different phenological stages.

Data collection

Plant growth parameters such as plant height, Soil plant analysis development (SPAD) values, dry weight, number of branches per plant were recorded in each plot from five randomly selected plants at different growth stage still harvest and yield attributes i.e., number of pods/ plant, number of seeds/plant, seed weight/plant, grain and straw yield were recorded at harvest. The SPAD values were estimated with the help of a SPAD meter (SPAD-502Plus, Konica Minolta, Japan) which gives an indirect value of chlorophyll content in plants. Dry weight has been taken by uprooting the plants in 25 cm row length and then kept in a hot air oven at 105±2°C for 48-72 h till constant weight was obtained. In case of intercropping system, the comparison in growth parameters data has been done on the basis of the principal crop (soybean) only. In case of intercropping system, crop equivalent yield (both grain and straw) was calculated by using the following formula.

Table 1: Treatment details of soybean-based cropping system during 2019-21

Treatment	Cropping system	Irrig. Level	Method of planting	Irrig. Method	Irrigation water applied, mm		Spacing (cm)	Fertilizer dose NPKS/ha
					2019	2020		
T_1	Soybean (control)	Rainfed	Flat bed	-			40×10	30:80:40:20
T_2	Soybean	66%ETc	Raised bed	Drip	39	45	45×25	30:80:40:20
T_3	Soybean	100% ETc	Raised bed	Drip	60	68	45×25	30:80:40:20
T_4	Soybean+Pigeonpea	66% ETc	Raised bed	Drip	44	52	45×25	30:80:40:20
							90×75	
T_5	Soybean+Pigeonpea	100% ETc	Raised bed	Drip	67	78	45×25	30:80:40:20
							90×75	
T_6	Soybean + Cotton	66% ETc	Flat bed	Sprinkler	52	64	40×10	30:80:40:20
							75×50	80:40:40:0
T_7	Soybean + Cotton	100% ETc	Flat bed	Sprinkler	78	96	40×10	30:80:40:20
							75×50	80:40:40:0

ETc = Crop evapotranspiration

$$\text{Crop equivalent yield (CEY)}=Cy + C1y \times \frac{Pc1}{Pc} \ldots,$$

Where, C_y is the yield of main crop, C_{1y} is the yield of intercrop, P_1 is the market rate of the intercrop, and PC is the market rate of the main crop. Also, water productivity was calculated from amount of water used for unit quantity of production using following formula.

$$\text{Water productivity}=\frac{\text{Economic yield (kg/ha)}}{\text{Water applied}(m^3/ha)}$$

Where, the quantity of water applied includes both water applied during supplemental irrigation as well as water received through precipitation.

Growing degree days

Growing degree days (GDD) were calculated for soybean crop in all the treatments using maximum temperature, minimum temperature and base temperature (Kaushik *et al.,* 2015). The base temperature was taken as 10 °C for soybean crop. The cumulative GDD were correlated with leaf area index for assessing the growth of soybean.

Table 2: Pearson correlation coefficient between soybean seed yield and weather variables during over pooled data 2019-20

	VS	FS	PFS-FDS	FDS-HMS
Maximum temperature	0.63*	-0.52	-0.61*	0.22
Minimum temperature	0.36	0.58*	0.69*	0.30
Rainfall	-0.58*	0.48	0.57	-0.41
Relative humidity-1	-0.28	-0.65*	0.42	-0.12
Relative humidity-2	-0.33	0.18	0.30	-0.24

VS-Vegetative stage; FS-Flowering stage; PFS-Pod filling stage; FDS-Full seed development; HMS- Harvestable maturity stage; * after the values indicate significant at p = 0.05

Table 3: Plant growth parameters and yield attributes of soybean based cropping system over 2019-21

Treatments	Plant height (cm)	No. of branches/plant	SPAD value	Dry weight (g)	No. of pods/plant	No. of seeds/ plant
T1	44.33[a]	6.29[d]	40.11[c]	76.46[a]	50.33[abc]	110.00[bc]
T2	41.67[a]	8.63[ab]	42.99[ab]	67.00[bc]	62.33[a]	157.50[a]
T3	40.10[a]	9.08[a]	43.79[ab]	65.71[c]	57.17[ab]	138.50[ab]
T4	27.21[c]	7.43[bcd]	45.05[a]	49.58[d]	38.83[c]	80.83[c]
T5	31.67[b]	7.67[bc]	42.63[abc]	45.50[e]	44.83[bc]	87.50[c]
T6	32.29[b]	6.77[cd]	41.57[bc]	70.88[b]	36.33[c]	85.17[c]
T7	34.79[b]	6.85[cd]	41.50[bc]	70.17[b]	39.33[c]	89.50[c]

Values within columns followed by different letters are statistically different at p = 0.05

Table 4: Soybean equivalent yield and water productivity in sole and intercropping system over the *kharif* season 2019-21

TR	Cropping system	Level of irrigation	Crop	Grain yield (t ha^{-1})	Soybean equivalent* Yield (t ha^{-1})	Straw/Stover yield (t ha^{-1})	Water productivity (kg/m^3)
T1	Soybean-sole crop	Rainfed	Soybean	1.64	1.64[c]		0.15[c]
T2	Soybean-sole crop	66%ETc	Soybean	1.89	1.89[c]		0.17[c]
T3	Soybean-sole crop	100%ETc	Soybean	1.86	1.86[c]		0.16[c]
T4	Pigeon pea+ Soybean	66% ETc	Soybean	1.26	3.92[b]	1.76	0.34[b]
			Pigeonpea	1.71		2.91	
T5		100% ETc	Soybean	1.31	4.08[b]	1.77	0.36[b]
			Pigeonpea	1.78		2.98	
T6	Cotton+ Soybean	66% ETc	Soybean	1.35	5.15[a]	1.43	0.44[a]
			Cotton	2.7		4.51	
T7		100% ETc	Soybean	1.41	5.37[a]	1.58	0.47[a]
			Cotton	2.81		4.72	

** Price of economic yield of Soybean, Pigeon pea & Cotton taken was ₹ 3710, 5800 & 5255 respectively, which was M.S.P. decided by the Government of India for the year 2019-2*

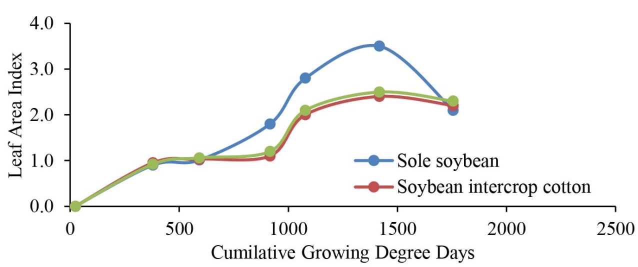

Fig. 1: Variation in leaf area index with cumulative growth degree days of soybean crop

Statistical analysis

The data of the two year experiments were statistically analyzed using standard procedures (Gomez and Gomez, 1984). The data were subjected to analysis of variance and F-test for determining the significance of the treatments. The differences between treatment means were compared using least significant difference at p = 0.05 and Duncan's Multiple Range Test (Rajwade *et al.*, 2018).

RESULTS AND DISCUSSION

Correlation of weather parameters with growth and yield of soybean

The leaf area index, a parameter of plant growth and development was estimated for soybean in sole as well as for intercropping system and plotted against cumulative growing degree days (GDD)(Fig. 1). It can be seen that under intercropping system, vegetative growth of soybean was negatively affected leading to lower leaf area index compared to sole soybean crop.

Pearson's correlation coefficient was estimated between weather parameters and soybean yield at different phenological stages for the pooled data of 2019-21 (Table 2). At the vegetative stage (VS), significant positive correlation was observed for maximum temperature and minimum temperature. However, relative humidity (RH-1 and RH-2) had negative correlation with seed yield during vegetative and flowering stages. During pod formation (PFS) to full development of seed (FDS) positive correlation was observed between rainfall, minimum temperature and humidity with seed yield, whereas maximum temperature had a negative association. Our results are in line with the results of Mishra and Cherkauer (2010) stating negative relation of maximum temperature during seed filling stage.

Plant growth parameters

Pooled analysis of two year data (2019-21) indicated different treatments had a significant effect on plant height (Table 3). However, difference in plant height was not significant when soybean was cultivated either on flatbed or on raised beds as sole crop. The lowest plant height (27.21 cm) was recorded in T_4 for the soybean crop which was intercropped with pigeon pea. The shade factor (height) of pigeon pea might have negatively affected the plant height of the soybean crop. Higher values of number of branches were recorded in T_3 may be due to more lateral branching on raised beds as compared to flatbeds (T_1). For dry matter accumulation, the difference among dry weights of different treatments was significant. The lowest values of dry weights were recorded in T_5 in soybean-pigeon pea intercropping at 100% ETc. As discussed earlier, shadow of the pigeon pea crop resulted in lower dry matter accumulation in the soybean crop Similarly, Maurya and Rathi (2000), also observed poor growth of soybean due to intercropping with Pigeon pea. In case of SPAD values, pooled analysis of two year data revealed significant difference among different treatments. Soybean in treatment T_4 produced significantly superior SPAD values than the rest of the treatments, while significantly inferior values of SPAD were recorded in T_1 suggests effect of long dry spells on chlorophyll formation.

Yield attributing characters

Statistical analysis of two years of data for yield attributing character showed significant differences among different treatments for the number of pods per plant, the number of seeds per plant, seed weight per plant and seed index (Table 3). Significantly superior values of the number of pods (62.33), and seeds (157.50) were recorded in treatment T_2 (66% ETc soybean). The sole crop of soybean on the raised bed might have resulted in the production of more pods due to better resource conservation on raised beds. These results are in agreement with the findings of Dhakad *et al*., (2020). The lowest values of the pods (36.33) were recorded in treatment T_6 for soybean crop (66% ETc, cotton+soybean). The cereal effect of cotton is the main reason for the lesser production of pods in treatment T_6.

Equivalent grain yield and water productivity

Pooled analysis of two-year data revealed significant differences among different treatments for equivalent grain as well as straw yield (Table 4). Treatment T_7 produced a significantly higher grain yield (5.37 t ha^{-1}), though at par with T_6. Khargkharate *et al.,* (2014) also reported cotton+soybean cropping systems as the highest yield and most remunerative among soybean with legume cropping. Maximum straw yield (5.34 t/ha^{-1}) was recorded in T_5, though it was at par with T_4. In pigeon pea+soybean based cropping system (T_4 and T_5), higher straw yield was recorded due to more vegetative growth as compared with reproductive growth.

Similar to grain yield, a significant difference was observed among different treatments for water productivity. Maximum water productivity (0.47 kg/m^3) was recorded in T_7, though it was at par with T_6 and T_5. Water used in supplemental irrigation has the highest marginal productivity and increase in production even under traditional practices (Sharma *et al.,* 2010). In cotton+soybean based cropping systems the exhaustive nature of cotton restricted the full growth potential of soybean, while the same cereal legume combination resulted in maximum equivalent grain yield and ultimately in maximum water productivity. Lower values of grain yield and water productivity in rainfed soybean reflects longer dry spells effect on the crop. The grain yield in each cropping system for 66% and 100% ETc irrigation levels was at par. It suggests a statistically insignificant yield penalty when the irrigation level is reduced to 66% from 100% ETc.

CONCLUSIONS

The present study was undertaken to evaluate sustainable soybean based cropping pattern during the *kharif* season in central India. The intercropping combination of soybean with cotton and/ or pigeon pea had better yield and cost economics than the sole cropping system. The study also concludes that the soybean as sole crop should be cultivated on raised beds to avoid water logging which frequently leads to crop failure. Different cropping systems irrigated at 66%ETc and 100%ETc, crop yield and water productivity were at par. Therefore, supplemental irrigation at 66%ETc would give better water productivity under limited water availability. While choosing the irrigation levels 66% must be preferred over 100%, which can save 34% of water without affecting the significant difference in yield.

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Data availability: Data shall be provided as per institute and funding agency policy.

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