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Evaluation of Factor Productivity and Effect of Individual Input of Production on Growth, Yield and Economics of Soybean [*Glycine max* (L.) Merrill]

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ABSTRACT

Background: In India, the area under soybean is steadily increasing, while production and productivity is low compared to the world average. To bridge this gap, factors of production determining the per-unit production plays a crucial role. In order to identify and quantify the factors of soybean production and their contribution, present study was undertaken.

Methods: The field experiments were conducted during *kharif* 2019 and 2020 in randomized block design with seven crop management practices for evaluation of effect of individual practice on soybean yield.

Result: Soybean grown with full practice (3221 kg ha^{-1}) gave significantly higher seed yield over omission of RDF (2489 kg ha^{-1}) and weed management (2560 kg ha^{-1}). Increase in seed yield with full practice over omission of RDF was 22.72% and over omission of weed management was 20.52%. The yield gap was higher with omission of RDF (732 kg ha^{-1}) and omission of weed management (661 kg ha^{-1}). Economic gain due to full practice was maximum over the omission of the practice. Least break-even cost was incurred with full practice (₹12.93 kg^{-1}), while higher with omission of weed management (₹14.81 kg^{-1}). Crop output efficiency in terms of partial factor productivity and agronomic efficiency was higher with full practice.

Key words: Factor productivity, Omission of practices, Soybean productivity, Sustainability.

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is a globally accepted oilseed and legume crop; it has 18-20% edible oil and high-quality proteins (38-40%) in its seed. It contributes 40 and 25% to the total oilseeds and edible oil production of the India and earns valuable foreign exchange by exporting soya meal (Agarwal *et al*., 2013). Its use has been increased as animal feed and protein-rich food products; also it has many more industrial uses to cater the human needs. Area under this crop has been increasing due to its potential uses and benefits. This is short duration cash earning economically beneficial crop (Francis *et al*., 2021) and help in restoring soil fertility through biological nitrogen fixation (Chianu *et al*., 2009), this enabled the farmers to grow the soybean crop extensively on a large area. However, India is lagging behind the world in terms of production and productivity due to the several constraints in production.

The success of soybean cultivation depends upon the factors of production, including non-monetary and monetary inputs, which plays a crucial role in the sustainable yield of this crop. Soybean requires optimum weather conditions, fertile and nutrient-rich soil, optimum cultivation and management practices to complete the growth and development (Agarwal *et al*., 2013). Seed yield and productivity declines if the production elements required for soybean crop are lacking and even result complete failure of the soybean crop as the severity prolongs. This turns to high economic loss to the soybean farming community. Lack of seed treatment to seeds before sowing with fungicide, insecticide and bio fertilizers, lack of weed management due to unavailability of labour or continuous rain, lack of sufficient soil moisture due to long dry spells during crop growth period, imbalanced nutrition, improper insect and disease management *etc*., affect the seed yield and productivity of soybean (Jaybhay *et al*., 2018). Optimum use of the resources for production *viz*., land, water, soil, weather, *etc*., along with production factors, add to higher soybean yield. Factors of production and management practices determine the success of crop husbandry for getting a sustainable yield of the crops. Information on the yield gap arising due to the absence/lack of individual crop management practices and quantifiable yield loss due to it is lacking. Hence, for understanding and studying the role of the components of soybean production, the present study with the objectives

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to evaluate the factor productivity for soybean and asses its effect on growth, yield, its components and economics of cultivation was undertaken.

MATERIALS AND METHODS

Field experiments were conducted during 2019 and 2020 (June to October) at research farm of MACS-Agharkar Research Institute, Pune, Maharashtra, India (18°14′ N latitude, 75°21′ E longitude and an altitude of 548.6 m from mean sea level). Total rainfall received during 2019 and 2020 from June to October was 793.1 mm and 978.4 mm respectively. An experiment was laid out in randomized block design (RBD) with three replications and each replication consisted of seven treatments *viz*., T_1: Full practice (Seed treatment, seed inoculation, recommended dose of fertilizer [RDF], weed management, insecticide application, sowing on ridges and furrow), T_2: Full practice - (omission/exclude) seed treatment, T_3: Full practice - seed inoculation, T_4: Full practice - RDF, T_5: Full practice - weed management, T_6: Full practice - insecticide application and T_7: Full practice - sowing on ridges and furrow. RDF 20 kg N+80 kg P_2O_5+20 kg K_2O ha^{-1} was supplied through inorganic fertilizers as basal application, as per the treatments. Soybean variety 'MACS 1188' was sown on the second fortnight of July in plots of size 3.6 m × 6 m (net plot 2.7 m × 5 m) with 45 cm row to row spacing on ridges and furrow and 5 cm spacing between the plants. Good crop condition was maintained and the crop was harvested manually after maturity. The data on bio metric obervations, yield and its attributes was recorded at the time of harvest whereas, the data on plant dry weight was recorded at 30, 45 and 60 days after sowing (DAS). The crop growth rate (CGR) and relative growth rate (RGR) was calculated as per the formula given by Watson (1947) and Williams (1946) as:

$$CGR=\frac{W_2 - W_1}{t_2 - t_1}$$

$$RGR=\frac{Log_{10} W_2 - Log_{10} W_1}{t_2 - t_1}$$

Where,

W_2 and W_1 are plant dry weight per plant at time period (t_2) and (t_1) respectively.

The economics of the treatments was calculated and the yield gap and other variables based on yield difference in various treatments under study were determined. Breakeven (BE) analysis was used to determine the values at which price, production, output and so on are adequate enough to cover specific costs (Cook *et al*., 2012 and Bhati *et al*, 2018). Crop output efficiency in terms of partial factor productivity (PFP) and agronomic efficiency (AE) of applied nutrients was determined as per the formulae given by Mengel and Kirkby (2001):

$$\text{PFP for N/P/K} = \frac{\text{Seed yield (kg ha}^{-1})}{\text{Rate of nutrient applied (kg ha}^{-1})}$$

$$\text{AE of nutrient} = \frac{\text{Yield (kg ha}^{-1}\text{) in nutrient applied plot} - \text{Yield (kg ha}^{-1}\text{) in control plot}}{\text{Nutrient (kg ha}^{-1}\text{) applied}}$$

The collected data were subjected to analysis of variance (ANOVA) using standard variance techniques suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect on growth attributes

Data presented in Table 1 reveals that the crop management treatments significantly influenced the growth attributes *viz*., plant dry matter at 45 and 60 DAS, CGR and RGR. Whereas, the values for plant height, number of branches per plant, dry matter per plant at 30 DAS and RGR at 45-60 DAS were non significantly influenced. The treatment T_1: Full practice recorded significantly higher number of pods per plant (58 pods) and significantly higher dry matter at 45 DAS (8.13 g plant^{-1}) and at 60 DAS (14.46 g plant^{-1}) over the treatment T_4: Full practice excluding RDF and closely followed by treatment T_6: Full practice - insecticide application and T_7: Full practice - ridges and furrow sowing. The values for CGR at 30-45 DAS (0.337 g m^{-2}day^{-1}) and at 45-60 DAS (0.421 g m^{-2}day^{-1}); and for RGR at 30-45 DAS (0.035 g m^{-1}day^{-1}) were significantly high in treatment T_1: Full practice over T_5: Full practice excluding weed management and rest of the treatments under study. Variation in the number of pods per plant, dry matter accumulation and growth rate due to different treatments might be attributed as positive assotiation with leaf area, number of leaves per plant and net assimilation rate of soybean plants (Malek *et al*., 2012). The differences in total dry matter accumulation in genotypes reflect differences in photosynthetic production (Bhattacharya, 2021).

Effect on seed yield and its attributes

The data on seed yield in various treatments was significantly different (Table 2). Soybean crop grown with T_1: full practice (3221 kg ha^{-1}) gave significantly higher seed yield over treatment T_4: full practice excludes RDF (2489 kg ha^{-1}) and T_5: full practice excludes weed management (2560 kg ha^{-1}) and was closely followed by rest of the treatments under study. Increase in seed yield under treatment T_1 over the T_4 was 22.72% and over T_5 it was 20.52%. Increment in seed yield due to full practice supported the essentiality of optimum cultivation practices required for obtaining the higher yield and evidenced the importance of individual cultivation practice to harvest maximum yield. Higher seed yield under treatment T_1: Full practice attributed to the maximum number of pods due to supply of all inputs and optimum management practices. Per cent decrease in yield under the treatments compared to full practice (T_1) presented in Fig 1. It showed decreasing order of an input/the management practice, which put forth the importance of an individual input/ the management practice for raising the soybean crop and obtaining optimum yield. Per cent increase

Table 1: Effect on growth and its attributes due to different treatments (Pooled data).

Treatments	Plant height (cm)	No. of branches plant^{-1}	No. of pods plant^{-1}	Dry matter plant^{-1} (g)			CGR		RGR	
				30 DAS	45 DAS	60 DAS	30-45 DAS	45-60 DAS	30-45 DAS	45-60 DAS
T_1: Full practice (Seed treatment, seed inoculation, RDF, Weed management, Insecticide application, Ridges and furrow sowing)	64.6	3.47	58	2.48	8.13	14.46	0.377	0.421	0.035	0.016
T_2: Full practice-seed treatment	59.83	3.20	52	2.54	6.75	12.44	0.28	0.379	0.029	0.018
T_3: Full practice-seed inoculation	63.27	3.00	51	2.34	6.55	11.53	0.28	0.333	0.03	0.016
T_4: Full practice-RDF	61.73	3.07	44	2.37	6.15	10.26	0.252	0.274	0.028	0.015
T_5: Full practice-Weed management	62.27	2.67	47	2.87	6.45	10.54	0.239	0.273	0.024	0.014
T_6: Full practice-Insecticide application	63.9	3.30	53	2.26	7.34	12.29	0.338	0.33	0.034	0.015
T_7: Full practice-Ridges and furrow sowing	62.47	2.33	52	2.54	7.23	11.86	0.313	0.308	0.03	0.015
SEm±	1.69	0.30	3.95	0.17	0.27	0.50	0.02	0.03	0.002	0.001
CD (P=0.05)	NS	NS	11.37	NS	0.77	1.42	0.06	0.09	0.007	NS

CGR: Crop growth rate (g m^{-2}day^{-1}), RGR: Relative growth rate (g g^{-1}day^{-1}).

in yield over full practice-RDF (T_4) was higher in all treatments except full practice - weed management (T_5) due to maximum yield loss. The results showed that the absence of RDF to supplement the nutrients, non removal of weeds that compete for resources and no insecticide application to manage the insect-pests contribute to maximum yield losses compared to rest of the crop management practices. Seed yield increase in soybean due to high input system was supported by the findings of Marburger *et al*. (2016).

Economics of study

Economic evaluation of the different treatments presented in Table 3 showed that the crop management with full practice (T_1) gave maximum gross returns (₹ 1,09,501/- ha^{-1}), net returns (₹ . 67,844/- ha^{-1}) and benefit: cost ratio (2.63:1) over full practice excluding RDF (T_4) and weed management (T_5); while these values in rest of the treatments were closely followed. Least net returns and benefit: cost ratio was observed with treatment T_5: full practice excluding weed management (₹ 49,125/- ha^{-1} and 2.32:1) followed by T4: full practice excluding RDF (₹ 50,239/- ha^{-1} and 2.47:1). The increase in the yield due to full practice (T_1) showed 27.59% and 25.94% increase in net returns over full practice excluding weed management (T_5) and excluding RDF (T_4), respectively. The yield gap in terms of yield reduction per hectare determined over the treatment full practice was recorded maximum under T_4: full practice excluding RDF (732 kg ha^{-1}) and T_5: full practice excluding weed management (661 kg ha^{-1}) followed by T_6: full practice excluding insecticide application (351 kg ha^{-1}). However, the least yield gap was recorded under treatment T_2: full practice excluding seed treatment (152 kg ha^{-1}), which showed it has least effect on soybean seed yield than other management practices. The value of differential yield based on the yield gap per hectare was maximum in treatment T_4: full practice excluding RDF (₹ 24,888/- ha^{-1}) followed by T_5: full practice excluding weed management (₹ 22,474/- ha^{-1}) while, it was least in T_2: full practice excluding seed treatment (₹ 5,168/- ha^{-1}). The differential cost per treatment determined over full practice was higher under T_4: full practice excluding RDF (₹ 7,282/- ha^{-1}) and T_5: full practice excluding weed management (₹ 3,750/- ha^{-1}) due to the absence of RDF and weed management. The incremental benefit: cost ratio determined considering the value of differential yield and differential cost was maximum in T_3: full practice excluding seed inoculation (59.84:1) and it was followed by T_2: full practice excluding seed treatment (20.67:1) than rest of the treatments. Higher incremental benefit: cost ratio with T_3: full practice excluding seed inoculation (59.84:1) and T_2: full practice excluding seed treatment (20.67:1) showed the highest factor productivity and was associated with a minimum cost of cultivation incurred on seed inoculation and seed treatment. The break-even yield determined based on the cost of cultivation and selling price of soybean varies from 948 kg ha^{-1} to 1041 kg ha^{-1}. Overall an average soybean yield needed to break even was 984 kg ha^{-1} to receive high returns under use of all the inputs of production, *i.e.* T_1: Full practice. However, the break-even cost per kilogram of soybean was maximum in treatment T_5: full practice excluding weed management (₹ 14.81/- kg^{-1}); it showed that more cost was incurred on the production of a kilogram of soybean per hectare. Whereas, least break-even cost was incurred in treatment T_1: full practice (₹ 12.93/- kg^{-1}). Break-even analysis gives accurate future profitability from soybean production (Billore *et al.*, 2020).

Crop output efficiency

Output efficiency in terms of partial factor productivity (PFP) and agronomic efficiency (AE) of applied nutrients to soybean crop presented in Table 4. PFP in terms of kilogram of grain produced to the kilogram of nutrient applied (Nitrogen, phosphorus and potash) was maximum with treatment T_1: Full practice followed by T_2: full practice excluding seed treatment and T_3: Full practice excluding seed inoculation, while the values for PFP of N, P and K were least under treatment T_5: full practice excluding weed management. However, AE of the applied nutrients (N, P and K) to soybean was recorded maximum in T_1: full practice followed by T_2: full practice excluding seed treatment and T_3: full practice excluding seed inoculation. Least AE was recorded with treatment T_5: full practice excluding weed management. These results are in agreement with McLaughlin *et al.* (2011), who reported that P fertilization increases nutrient use efficiency and partial factor productivity. PFP is a measure of efficiency that includes production per unit of nutrient applied Rose *et al.* (2012). Yuan and Xu (2011) reported that PFP indicates how productive a crop in comparison to its nutrient input is. Similarly, Mujeeb *et al.* (2010) reporeted that the application of all the organic and inorganic inputs significantly increased the agronomic efficiency of nutrients applied to the soils. The results of study revealed that soybean crop grown with all management practices comprising land preparation, seed treatment, seed inoculation, balanced nutrition, water, weed management, insect-pest and disease management gives optimum seed yield. An absenec of the factors of production significantly affects the growth, yield attributes, seed yield and the

Table 2: Soybean yield and its attributes influenced due to various treatments (Pooled data).

Treatment	Seed index (g)	Straw yield (kg ha^{-1})	Harvest index (%)	Seed yield (kg ha^{-1})	% decrease in yield compared to T1	% increase in yield over T4
T_1: Full practice (Seed treatment, Seed inoculation, RDF, Weed management, Insecticide application, Ridges and furrow sowing)	14.48	3047	51.34	3221	-	22.73
T_2: Full practice-seed treatment	14.32	2631	53.84	3069	4.72	18.90
T_3: Full practice-seed inoculation	14.50	2593	53.94	3045	5.46	18.26
T_4: Full practice-RDF	14.38	2753	47.43	2489	22.73	-
T_5: Full practice-weed management	14.22	2781	48.34	2560	20.52	2.77
T_6: Full practice-Insecticide application	14.62	2841	51.13	2870	10.90	15.31
T_7: Full practice-ridges and furrow sowing	14.80	2875	50.57	2972	7.73	16.25
SEm±	0.44	206.87	1.31	208.35	-	-
CD (P=0.05)	NS	NS	3.76	599.22	-	-

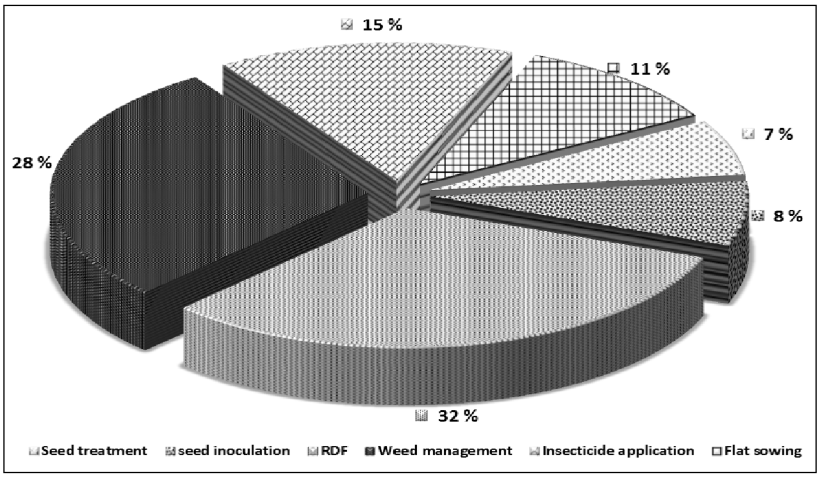

Fig 1: Percent contribution of production factors to soybean yield on the basis of yield reduction compared to full practice (T1).

Table 3: Effect on economics soybean production under various treatments (Pooled data).

Treatment	Seed yield (kg ha^{-1})	Gross returns (₹ ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net returns (₹ ha^{-1})	B: C ratio	Yield gap (kg ha^{-1})	Value of differential yield (₹ ha^{-1})	Differential cost (₹ ha^{-1})	IBCR	Break even yield (kg ha^{-1})	Break-even cost (₹ kg^{-1})
T_1: Full practice (Seed treatment, Seed inoculation, RDF, weed management, Insecticide application, Ridges and furrow sowing)	3221	109501	41657	67844	2.63:1	-	-	-	-	1041	12.93
T_2: Full practice-seed treatment	3069	104351	41407	62944	2.53:1	152	5168	250	20.67	1035	13.49
T_3: Full practice-seed inoculation	3045	103528	41557	61971	2.49:1	176	5984	100	59.84	1039	13.65
T_4: Full practice-RDF	2489	84614	34375	50239	2.47:1	732	24888	7282	3.42	859	13.81
T_5: Full practice-weed management	2560	87032	37907	49125	2.32:1	661	22474	3750	5.99	948	14.81
T_6: Full practice-insecticide application	2870	97567	39157	58410	2.50:1	351	11934	2500	4.77	979	13.64
T_7: Full practice-ridges and furrow sowing	2972	101051	39557	61494	2.56:1	249	8466	2100	4.03	989	13.31
SEm$\pm$	208.35	7083	473	8916	0.21	-	-	-	-	-	-
CD (P=0.05)	599.22	20372	1359	25644	0.59	-	-	-	-	-	-

IBCR: Incremental benefit cost ratio.

Table 4: Crop output efficiency in terms of partial factor productivity (PFP) and agronomic efficiency (AE) of applied nutrients.

Treatment	Seed yield (kg ha^{-1})	% Yield over reduction full practice	PFP			AE		
			N	P	K	N	P	K
T1: Full practice (Seed treatment, Seed inoculation, RDF, Weed management, Insecticide application, Ridges and furrow sowing)	3221	-	161	40	161	36.60	9.15	36.60
T2: Full practice- seed treatment	3069	4.72	153	38	153	29.00	7.25	29.00
T3: Full practice- seed inoculation	3045	5.46	152	38	152	27.80	6.95	27.80
T4: Full practice- RDF	2489	22.73	-	-	-	-	-	-
T5: Full practice- Weed management	2560	20.52	128	32	128	3.55	0.89	3.55
T6: Full practice- Insecticide application	2870	10.90	144	36	144	19.05	4.76	19.05
T7: Full practice- Ridges and furrow sowing	2972	7.73	149	37	149	24.15	6.04	24.15

economic benefits from the soybean. Recommended dose of fertilizer and weed management are major factors contributing to soybean yield loss and attributed to maximum yield gaps compared to full practice.

CONCLUSION

From the present study, it can be concluded that the soybean crop requires all the optimum inputs and management practices for obtaining the higher seed yield. An absence/ omission of the factors of production significantly affects the growth, yield attributes, seed yield and the economic benefits from the soybean. Recommended dose of fertilizer for supplying the nutrition and weed management are the one of the major factors contributing to soybean yield loss and attributed to maximum yield gap compared to full practice comprising all management practices and omission of the other factors of production. The crop output efficiency in terms of partial factor productivity and agronomic efficiency was maximum with full practice comprising all factors of production compared to the omission of the recommended dose of fertilizers and weed management.

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