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

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ABSTRACT

Background: In the face of limited resources and changing climatic conditions, a major challenge for agriculturists is to ensure food security while addressing the issue of an ever-growing population. In India, the average productivity of soybean is low as compared to world average due to lack of improved agronomic practices, less importance and mostly grown under rain-fed condition. To bridge this gap, factors of production determining the per-unit production plays a crucial role in crop production. Therefore, in order to identify/evaluate the partial factor productivity and their contribution for better crop growth and individual input use efficiency study was undertaken.

Methods: The field experiments were conducted during *Kharif* 2020, 2021 and 2022 in Randomized Block Design with seven crop management practices. To know the efficiency of individual crop management practices on growth, yield parameters, yield, economics and output efficiency in terms of partial factor productivity and agronomy efficiency of applied nutrients.

Result: Three-year results concluded that**,** soybean grown with full package recorded significantly higher seed yield (2277 kg ha^{-1}) over full package excluding weed management (1889 kg ha^{-1}) and full package excluding RDF (2023 kg ha^{-1}). The yield gap was higher with omission of weed management (388 kg ha^{-1}) and omission of RDF (254 kg ha^{-1}). Further, net returns and crop out-put efficiency in terms of partial factor productivity and agronomic efficiency was higher with full package over the omission of the practice. Thus it can be concluded that, for achieving higher productivity, profitability and agronomic efficiency of applied nutrients under full package comprising all crop management practices can be adopted over the years in Northern Transition Zone of Karnataka.

Key words: Agronomic efficiency, Economics, Factor Productivity, Growth, Soybean.

INTRODUCTION

Soybean (*Glycine max* (L.) Merill) has become the most important oilseed crop of India in terms of both area and production and is significantly contributing to country's edible economy. In India it is grown over an area of 11.44 million hectare with a production of 12.04 million tonnes and average productivity of 1050 kg ha^{-1} (Anonymous, 2022). In India average productivity is low as compared world average (1600 kg ha^{-1}) (Anonymous, 2023). Soybean mainly grown in the rainfed condition and it is important for the livelihood of small and marginal farmers. Soybean contributes 43 per cent to the total oilseeds and 25 per cent to the total oil production in India and ranks fourth in respect to production of soybean in the world (Tomar *et al.,* 2018 and Kumawat *et al.,* 2021)

In India, average productivity of soybean is low due to lack of seed treatment with 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 pest and disease management *etc*., affect the seed yield and productivity of soybean (Jaybhay *et al*., 2018). In general, total annual loss in agriculture produces, weeds account for 45%, insect 30%, disease 20% and other pests 5% (Rani and Raju, 2020). Vagaries of monsoon and prolonged dry spells affect crop growth and yield and significantly in Dharwad region of

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Karnataka. Even under normal rainfall situation crop failures are occurring due to moisture stress due to occurrence of dry spells occurred particularly during critical crop growth stages (Verma *et al.,* 2018). For sustainable production, suitable in-situ conservation practices may ensure higher productivity by saving the crops during limiting and non-limiting moisture condition through safe disposal of runoff or its retention for profile moisture as and when required. Hence, it is necessary to exploit the technologies for *in-situ* moisture conservation like tillage, land configurations, mulching *etc*. (Rajput *et al.,* 2009 and Mohanty *et al.,* 2017).

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 (Jaybhay *et al.,* 2022). Hence, optimum use of the resources for production *such as.,* land, water, soil and weather, *etc*., along with integrated crop production factors, add to higher soybean yield (Jaybhay *et al*., 2018).

Factors of production and integrated management practices determine the success of crop husbandry for getting a sustainable yield of the crops. Only few of the literature was suggested that, soybean grown with full practice gave significantly higher seed yield and net income, over omission of RDF and weed management. Further crop output efficiency in terms of partial factor productivity and agronomic efficiency was higher with full practice (Jaybhay *et al.,* 2022). 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 in Northern Transition Zone of Karnataka.

Taking all these above factors into account, the current study was conducted over three years to assess how various crop management practices would impact on growth, yield and yield parameters, economics and crop output efficiency of partial factor productivity and agronomic efficiency of applied nutrients under rainfed conditions.

MATERIALS AND METHODS

Experimental site

Field experiments were conducted during the *kharif* season of 2020, 2021 and 2022 at All India Co-ordinated Research Project (AICRP) on Soybean, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka, India under rainfed conditions. Dharwad is located at 15°17′ North latitude and 70°05′ East longitude with an altitude of 678 m above the mean sea level (MSL). It is located at Zone-8 *i.e.* Northern transitional zone and receives an annual rainfall of 800 to 1000 mm distributed throughout the growing season. The details of experimental site characteristic (Table 1) and meteorological data of study area are presented in Fig 1.

Experimental design and treatment details

The experiment was conducted in randomized block design with seven crop management practices with three replications. T_1. Full package (Seed treatment, seed inoculation, RDF, weed management, insecticide application, Ridge and furrow sowing), T_2. Full package - seed treatment, T_3. Full package - seed inoculation, T_4. Full package - RDF, T_5. Full package - weed management, T_6. Full package - insecticide application and T_7. Full package - Ridge and furrow sowing. The net plot size of the experimental site was 2.4 × 4.6= 11.04 m^2. The cultivar of soybean used in the study was MACS 1188. The treatment details on full package given in Table 2.

Collection of data on growth, yield and its components of soybean

Observations were recorded on number of branches per plant, total dry matter production, number of pods per plant and test weight. Grain and straw yield were calculated

Table 1: Details of experimental site.

	Details of experimental site
Agroclimatic zone	Northern Transition Zone (VIII)
State and district	Karnataka and Dharwad
Coordinates of the site	15.4461072 Latitude and 74.9986732 Longitude
Mean annual rainfall (mm)	838.0 mm
Major soil type	Black cotton soil (*Vertisol*)
Available nutrient status (kg ha^{-1})	N-187, P_2O_5 - 23 and K_2O-291
Major crops grown	Maize, Wheat, Cotton, Soybean, Chickpea
Growing period temperature (°C)	June (29.4, 28.3 and 29.9) July (27.5, 27.2 and 26.6), August (26.1, 28.0 and 27.4), September (28.4, 28.0 and 28.7) months (Fig 1)
Date of sowing	04.07.2020, 22.06.2021 and 15.06.2022

based on the yield obtained from each net plot and converted into to kg ha^{-1} and also economics workout.

Crop output efficiency in terms of partial factor productivity and agronomic efficiency

PFP and AE was determined as per the formulae given by Mengel and Kirkby (2001).

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

Where:
PFP- Partial factor productivity.

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

Where:
AE- Agronomic efficiency of applied nutrients.

Statistical analysis

The statistical analysis of data on various recorded parameters of growth, yield and economics was done by using randomized block design as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth attributes of soybean

Pooled data of three years presented in Table 3 revealed that the different crop management practices/treatments, significantly influenced the growth parameters *viz.*, plant height, number of branches per plant and total dry matter

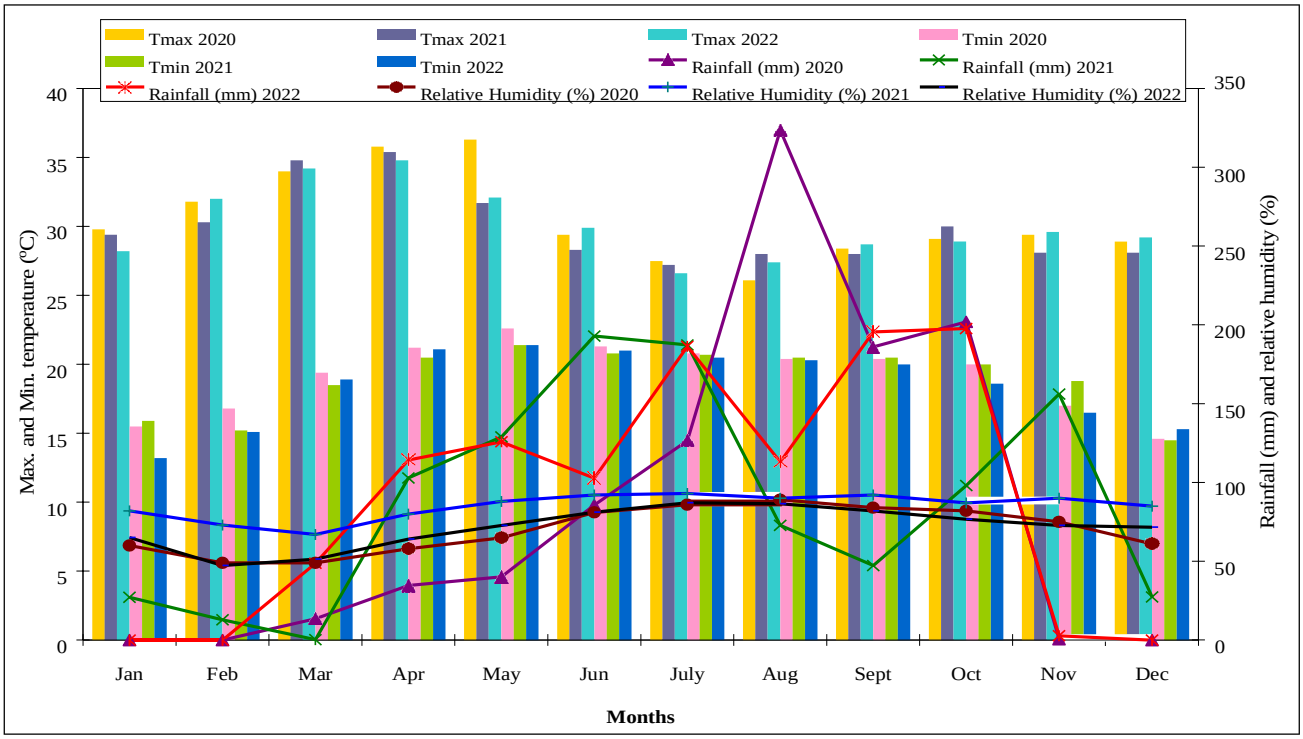

Fig 1: Mean monthly meteorological data of experimental site during 2020, 2021 and 2022.

Table 2: Treatment details on full package.

Particulars	Details
Seed treatment	Seed treatment with Carboxin + Thiram @ 3 g/kg of seeds
Seed inoculation	Microbial culture with Rhizobium and PSB
RDF (Kg ha^{-1})	FYM @ 6 t/ha, N:P_2O_5:K_2O:S: 20:80:25:20 kg/ha respectively
Weed Management	Pre-Emergent application of Pendimethalin 30 EC @ 4 ml/l + one intercultivation at 25 DAS and one hand weeding at 40 DAS
Insecticide application	Lambda cyhalothrin @ 0.5 ml/L @ 25 DAS against early defoliators at vegetative stage + Coragen @ 0.2 ml/L @ 45 DAS against defoliators at vegetative stage + Spinosad @ 0.2 ml/L @ 70 DAS against pod borer at pod formation stage
Ridge and furrow sowing	30 cm × 10 cm spacing

production at 60 DAS. Among the different treatments, full package (T_1) recorded significantly higher plant height (65.80 cm), number of branches per plant (5.85) and total dry matter production (69.52 g plant^{-1}) at 60 DAS. However, it was on par with full package excluding seed treatment (T_2). Whereas, significantly lower plant height (54.12 cm), number of branches per plant (4.42) and total dry matter production (56.85 g plant^{-1}) was noticed in full package excluding weed management (T_5). The higher growth attributes which might be due to efficiently crop management practices resulted in higher dry matter production. The similar results are close conformity with the findings of Jaybhay *et al.* (2022).

Yield attributes and yield of soybean

Significantly higher yield attributes *viz.,* number of pods per plant (76.0), seed yield per plant (32 g) and test weight (14.6 g) and seed yield (2277 kg ha^{-1}) was recorded in full package (T_1). However, it was on par with full package excluding seed treatment (T_2) and full package excluding ridge and furrow sowing (T_7). Whereas, lower number of pods per plant (61.0), seed yield per plant (24.78 g) and test weight (13.5 g) and seed yield (1889 kg ha^{-1}) recorded in full package excluding weed management practice (T_5) (Table 2 and 3) (Fig 2). Increase in seed yield under treatment T_1 over the T_5 was 17.03 per cent and over T_4 it was 11.15 per cent. Increment in yield and yield attributes due to full package supported by the essentiality of optimum cultivation practices required for obtaining the higher yield and evidenced the importance of individual cultivation practice to harvest maximum yield. The similar results with the findings of Jaybhay *et al.* (2022) and Meena *et al.* (2022). The yield gap in terms of yield reduction per hectare determined over the treatment full package was

Table 3: Effect of different treatments on growth and yield parameters of soybean (Pooled for 3 Years).

Treatments	At 60 DAS			Yield parameters at harvest		
	Plant height (cm)	Number of branches per plant	Total dry matter production (g plant^{-1})	Number of Pods per plant	Seed yield per plant (g)	Test weight (g)
T_1: Full package (Seed treatment, seed inoculation, RDF, weed management, insecticide application, Ridge furrow)	65.80	5.85	69.52	76	32.0	14.6
T_2: Full package - seed treatment	63.45	5.65	68.20	75	31.2	14.4
T_3: Full package - seed inoculation	62.02	5.00	63.85	69	28.56	14.2
T_4: Full package - RDF	58.65	4.80	60.25	67	25.10	14.0
T_5: Full package - weed management	54.12	4.42	56.85	61	24.78	13.5
T_6: Full package - insecticide application	60.12	4.90	62.52	67	25.85	13.9
T_7: Full package - ridge and furrow sowing	62.24	5.22	66.20	72	30.24	14.3
S.Em +	1.23	0.35	1.28	2	1.02	0.4
C.D (P=0.05)	3.14	0.84	3.25	6	3.01	NS

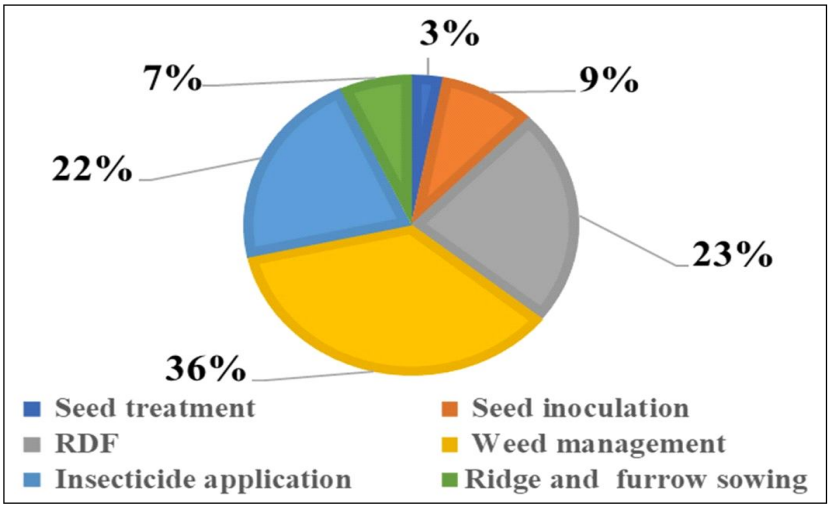

Fig 2: Per cent contribution of production factors to soybean yield on the basis of yield reduction compared to full practice (T1).

recorded maximum under full package excluding weed management (388.0 kg ha^{-1}) and full practice excluding RDF (254 kg ha^{-1}) followed by full practice excluding insecticide application (233 kg ha^{-1}). However, the least yield gap was recorded under full practice excluding seed treatment (33 kg ha^{-1}), which showed it has least effect on soybean seed yield than other management practices (Table 4). The similar results are close conformity with the findings of Jaybhay *et al.,* (2022).

Economics of soybean

Economics of different treatments are presented in Table 4. The pooled data of three years, observed that, significantly higher gross returns (Rs. 97843 ha^{-1}) and net returns (Rs. 57043 ha^{-1}) was recorded in crop management with full package (T_1). However, it was on par with full package excluding seed treatment (T_2) and full package excluding ridge and furrow sowing (T_7). Whereas, significantly lowered gross return (Rs. 80590 ha^{-1}) and net returns (Rs. 44695 ha^{-1}) was noticed in full package excluding weed management (T_5).

The value of differential yield based on the yield gap per hectare was maximum in full package excluding weed management (Rs. 16684 ha^{-1}) followed by full package excluding RDF (Rs. 10992 ha^{-1}) and full package excluding insecticide application (Rs. 10019 ha^{-1}). While, it was least in full package excluding seed treatment (Rs. 1419 ha^{-1}). The similar results are close conformity with the findings of Jaybhay *et al.* (2021).

Crop output efficiency

The crop output efficiency in terms of partial factor productivity (PFP) and agronomic efficiency (AE) of applied nutrients to soybean crop are presented in Table 5. PFP in terms of kilogram of grain produced to the kilogram of nutrient applied (NPK) was higher with Full package (T_1) followed by full package excluding seed treatment (T_2) and Full package excluding ridge and furrow sowing (T_7). Whereas, lower PFP values under full package excluding weed management (T_5). Similarly, higher agronomic efficiency of applied nutrient (NPK) to soybean was recorded maximum in Full package (T_1), followed by full package excluding seed treatment (T_2) and full package excluding ridge and furrow sowing (T_7). Whereas, negative agronomic efficiency was observed in full package excluding weed management (T_5).

PFP is a measure of efficiency that includes production per unit of nutrient applied (Rose *et al*., (2012). Further similar results noticed by (Lohar and Hase, 2022) the integrated application of chemical fertilizer + FYM and chemical fertilizer + vermicompost was found to be highly effective to improve soil health and productivity through improved sustainability attributes like agronomic efficiency, partial factor productivity and sustainable yield index in soybean.

Table 4: Effect of different treatments on yield and economics of soybean (Pooled for 3 Years).

Treatments	Seed yield (kg ha^{-1})	Yield gap (kg ha^{-1})	% Yield over reduction full practice	Value of differential yield (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C
T_1: Full package (Seed treatment, seed inoculation, RDF, weed management, insecticide application, Ridge furrow)	2277	-	-		97843	57043	2.39
T_2: Full package-seed treatment	2244	33	1.44	1419	96215	55492	2.36
T_3: Full package-seed inoculation	2176	101	4.43	4343	93503	52846	2.30
T_4: Full package-RDF	2023	254	11.15	10922	87334	48946	2.42
T_5: Full package-weed management	1889	388	17.03	16684	80590	44695	2.25
T_6: Full package-insecticide application	2044	233	10.23	10019	87102	48462	2.26
T_7: Full package-ridge and furrow sowing	2202	75	3.30	3225	94564	56423	2.48
S.Em +	69	-	-	-	2541	1531	0.07
CD (P=0.05)	214	-	-	-	7831	4716	NS

Table 5: Effect of different treatments on partial factor productivity and agronomic efficiency of soybean (Pooled for 3 Years).

Treatments	Seed yield (kg ha^{-1})	Partial factor productivity			Agronomic efficiency		
		Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
T_1: Full package (Seed treatment, seed inoculation, RDF, weed management, insecticide application, Ridge and furrow sowing)	2277	57	28	91	6.35	3.17	10.16
T_2: Full package-seed treatment	2244	56	28	90	5.52	2.76	8.84
T_3: Full package-seed inoculation	2176	54	27	87	3.82	1.91	6.12
T_4: Full package-RDF	2023	-	-	-	-	-	-
T_5: Full package-weed management	1889	47	24	76	-3.35	-1.67	-5.36
T_6: Full package-insecticide application	2044	51	26	82	0.52	0.26	0.84
T_7: Full package-ridge and furrow sowing	2202	55	27	88	4.47	2.23	7.16

CONCLUSION

The long-term results concluded that, the soybean crop requires all the optimum inputs and management practices for obtaining the higher productivity. An absence/omission of the factors of production significantly affects the growth, seed yield and the economic benefits from the soybean. The weed management and recommended dose of fertilizers are the major factors contributing to soybean yield loss and attributed to maximum yield gaps compared to full package. Thus, it can be concluded that, for achieving higher productivity, profitability and agronomic efficiency of applied nutrients under full package comprising all crop management practices can be adopted over the years in Northern Transition Zone of Karnataka.

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Conflict of interest

All authors declared that there is no conflict of interest.

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