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Influence of Bioformulations on Productivity, Profitability and Quality in Soybean under Rainfed Condition of Northern Transition Zone of Karnataka

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ABSTRACT

Background: Soybean [*Glycine max* (L.) Merrill] is the most important major oilseed crop among the edible oil seed crops. It has emerged as a potential protein as well as oilseed crop worldwide. The average productivity of soybean is low due to less importance and mostly grown under rain-fed condition without using bio-fertilizers (novel bio-formulations). Hence the current study was carried out to enhance the productivity and profitability of soybean under rainfed condition.

Methods: The present investigation was carried out at AICRP on Soybean, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad with medium deep black soil under rainfed condition. The experiment was executed in a Randomized Block Design with three replications and seven treatments. The influence of bioformulations on growth, yield parameters, yield, economics, quality and nutrient status of soybean (DSb 21) was carried out during *kharif* 2021-22 and 2022-23.

Result: The pooled data of two years concluded that, application of 100% RDF alone (T_2) was recorded significantly higher dry matter production (79.2 g plant^{-1}), pods per plant (64.0), seed index (14.41 g), seed yield (2,797 kg ha^{-1}) and straw yield (4,340 kg ha^{-1}) and similarly higher uptake of nitrogen (103.74 kg ha^{-1}), phosphorus (17.54 kg ha^{-1}) and potassium (91.40 kg ha^{-1}) in soybean crop followed by next best treatment with application of 75 per cent RDF + *Rhizobium* + MDSR14 + 12c (76.6 g plant^{-1}, 61.6, 14.19 g, 2,631, 4,170, 100.12, 16.73 and 86.64 kg ha^{-1} respectively) (T_7) as compared to other treatments. Further, higher net returns (Rs.1,13,015 ha^{-1}) and benefit cost ratio (4.73) was also obtained in T_7. Therefore, the application of 75 per cent RDF + *Rhizobium* + MDSR14 + 12c can be recommended for eco-friendly, economically viable, environmentally sound and sustainability in nature, besides improving the physico chemical properties of soil and in turn higher productivity and profitability under medium deep black soil in Northern Transition zone of Karnataka (India).

Key words: Bio-formulation, Nutrient uptake, Productivity, Profitability, Soybean.

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is also known as Golden Bean or Miracle crop, as they contain a complete source of protein and oil (Liu *et al*., 2020 and Talukdar *et al*., 2013). Soybean is mainly grown for their seeds and it is the second largest oil seed after groundnut in India. Soybean seeds contain 43.2% protein, 19.5% fat, 20.9% carbohydrate and a good amount of other nutrients like calcium, phosphorus, iron and vitamins (Gupta *et al*., 2003 and Immadi *et al*., 2021). 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). Predominant soybean growing states in India are Madhya Pradesh, Maharashtra, Rajasthan andhra Pradesh, Karnataka and Gujarat. In Karnataka, soybean occupies an area of 0.43 million hectare with a production of 0.44 million tonnes and productivity of 1055 kg ha^{-1} (Anonymous, 2023).

The average productivity of soybean is low due to less importance and mostly grown under rainfed condition without using bio-fertilizers (Sharma *et al*., 2023). Regular depletion of nutrient resources of soil has led to emergence of several nutrients deficiencies in soil and this because of intensive production, the higher and faster are the rates of nutrients exhaustion from the soil (Jain *et al*., 2021). Though, chemical fertilizers are playing a crucial role to meet the nutrient requirement of the crop, persistent nutrient depletion is posing a greater threat to the sustainable agriculture. Therefore, there is an urgent need to reduce the usage of chemical fertilizer and in turn, increase in the usage of novel bio-formulated products.

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Biofertilizers helps to increase microbial activity in soil to solubilize and mobilize the nutrients to reach the plant roots (Dai *et al*., 2004 and Basamma *et al*., 2013). The application of biofertilizers enhances the nutrient levels of soil which support plant growth and productivity in agricultural field (Kumar and Meena, 2020). Liquid and solid biofertilizers having a variety of beneficial microorganisms may restore soil fertility by activating soil microorganism, which can enhance the crop yield and quality. Liquid biofertilizers have the capacity to replace the traditional chemical fertilizers and carrier based biofertilizers which play a major role in restoring the soil health (Lavanya *et al*., 2018).

Bio-source mediums such as Bio-NPK liquid microbial consortium contain mixed populations of N-fixing bacteria (*Azotobacter crococum*), P-solubilizing bacteria (*Paenibacillus tylopilii*), K-solubilizing bacteria (*Bacillus decoloration*) and Bio-ZN liquid contains a single population of Z-solubilizing bacteria (*Bacillus endophyticus*). These inoculants help in meeting the nutrient demands of crops through proper nitrogen fixation by enhancing nodulation, solubilization of insoluble phosphorus, mobilizing potassium and zinc (Sharma *et al*., 2023). The seed treatment with suitable *rhizobium* culture before sowing can increase pulse production to an extent of 10-15 per cent (Pradip Kumar and Sharma, 2018). The application of RDF + *Rhizobium* + PSB to soybean crop resulted in higher productivity due to the cumulative effect of auxins, cytokinins and gibberellins on growth contributing characters and ultimately enhanced yield (Kumawat *et al*., 2019). Incorporating bio-fertilizers into the soil combined with inorganic fertilizers increases crop productivity and maintains soil health for a longer period of time (Manna *et al*., 2007).

For considering all the above factors, hence, use optimum dose of fertilizer in conjunction with novel bioformulations assumes special attention for their economically viable, eco-friendly, environmentally sound and sustainability in nature, besides improving the physico chemical properties of soil and in turn productivity (Mahmud *et al*., 2021). Therefore, taking into consideration the above facts, a field experiment was conducted to know the influence of chemical fertilizers and in conjunction with different novel bio-formulation to enhance productivity, profitability and quality of soybean.

MATERIALS AND METHODS

Experimental site

Field experiment was conducted at All India Co-ordinated Research Project on Soybean, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka, India under rainfed conditions during *kharif* 2021-22 and *kharif* 2022-23. The soil of the experimental site was medium black which belongs to the order *Vertisol* that was popularly known as “black cotton soil”. The available soil status N, P and K were 186, 22 and 290 kg ha^{-1} and micro nutrients Zn and Fe were 0.68 and 8.31 mg kg^{-1} respectively. The total rainfall of 1055 mm and 1088 mm were received during experimental year 2021-22 and 2022-23, respectively as compared to normal rainfall of 815 mm.

Experimental design and treatment details

The experiment was laid out in Randomized Complete Block Design with seven treatments in combinations with three replications. Treatment details such as, T_1: Control; T_2: Recommended dose of fertilizers (RDF); T_3: 75% RDF; T_4: 75% RDF + Bio-Zn; T_5: 75% RDF + Bio-NPK; T_6: 75% RDF + Bio-Zn + Bio-NPK and T_7: 75 % RDF + *Rhizobium* + MDSR14 + 12c (12c= *Burkholderia arboris* - High P solubilizing bacteria)**.** The dose of RDF were 40:80:25, (N: P_2O_5:K_2O kg ha^{-1}) at basal dose through urea, single super phosphate and murate of potash, respectively and seed treatment with Bio-NPK and Bio-Zn @ 250 ml and *Rhizobium japonium* @ 200 ml for the seed of one hectare. 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 DSb 21.

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

Crop was raised with recommend package of practices. Observations were recorded on dry matter production, number of nodules, fresh and dry weight of nodules, number of pods per plant and seed index. Grain and straw yield was calculated based on the yield obtained from each net plot and converted into to kg ha^{-1}. Quality, economics, nutrient uptake and availability analyzed as per the treatments. The data on different parameters were analysed statistically by adopting Fisher’s method of ANOVA suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Bioformulations on dry matter production

The perusal of pooled data of two years presented in Table 1 revealed that, dry matter production per plant was significant at 30, 45 DAS and at 60 DAS. Among the different treatments, significantly higher dry matter production (9.9, 39.1 and 79.2 g $plant^{-1}$, respectively at 30, 45 DAS and at 60 DAS) was recorded with application of 100% RDF alone (T_2) followed by next best treatment with application of 75 per cent RDF + *Rhizobium* + MDSR14 + 12c (9.2, 38.4 and 76.6 g $plant^{-1}$) respectively at 30, 45 and at 60 DAS. Whereas, significantly lower dry matter production (7.6, 30.0 and 61.6 g $plant^{-1}$ respectively at 30, 45 and 60 DAS) was recorded in control (T_1). Similar trends was noticed during individual years. This increase in dry matter accumulation which might be due to great availability of macro and micro nutrients from both inorganic sources and bioformulations. Inorganic fertilizers offer nutrients to the plant which are readily soluble in soil solution and thereby instantly available to the plants. These results were in conformity with Devi *et al*. (2013) and Verma *et al*. (2017) wherein

inorganic fertilizers conjunctively maximizing the yield as well maintaining soil health and productivity with organic manure. Great availability of nutrients with the combined application of inorganic source and biofertilizers or bioformulations seems to have promoted various physiological activities of plant thus growth and development of the plant. Similar findings were also reported by Dipak *et al.* (2018) and Meena *et al.* (2021) in soybean.

Bioformulations on number of nodules and fresh and dry weight of nodules

Number of nodules, fresh and dry weight of nodules as influenced by novel bioformulations is presented in Table 2. The pooled data of two years indicated that, application of 75 per cent RDF + *Rhizobium* + MDSR14 + 12c recorded significantly higher number of nodules (23.6), fresh weight of nodules (1.96 g) and dry weight of nodules (84.0 mg) at full blooming stage (R2) of soybean as compared to other treatments. Whereas, significantly lower number of nodules (11.1), fresh weight of nodules (0.95 g) and dry weight of nodules (66.0 mg) was recorded in control (T_1). The similar trend was also followed at initial seed filling stage (R5) (Table 3). The higher nodules and dry weight which might be due to greater availability of nutrients in the soil and better nodulation under the influence of inoculation (*Rhizobium* and phosphate solubilizing bacteria) resulted in better growth and development which might be attributed to better mobilization of phosphorus and might be increased number of nodules and dry weight. These findings are in accordance with the results of Devi *et al.* (2013) and Jaga and Sharma (2015) reported that, in soybean, dual inoculation of VAM + *Rhizobium* and VAM + PSB along with chemical fertilizers gave higher number of nodules (37.3, 37.5) which was 76.0 per cent higher over control.

Bioformulations on yield parameters

Pooled data revealed that, bioformulations significantly influenced on yield parameters is presented in Fig 1. Significantly higher number of pods per plant (64.0) and

Table 1: Effect of novel bio formulations on plant dry matter production of soybean at different growth stages.

Treatments	Plant dry weight (g) at 30 DAS)			Plant dry weight (g) at 45 DAS			Plant dry weight (g) at 60 DAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1: Control	7.4	7.7	7.6	31.8	28.1	30.0	62.3	60.9	61.6
T_2: RDF only	9.6	10.2	9.9	36.8	41.4	39.1	77.4	81.0	79.2
T_3: 75% RDF	7.6	7.9	7.8	32.0	29.8	30.9	64.6	62.3	63.4
T_4: 75% RDF + Bio Zn	8.4	8.2	8.3	33.2	32.0	32.6	71.7	64.2	68.0
T_5: 75% RDF + Bio NPK	8.6	8.8	8.7	34.2	32.9	33.5	72.6	65.6	69.1
T_6: 75% RDF + Bio Zn + Bio NPK	8.7	9.1	8.9	35.0	35.7	35.3	74.3	73.5	73.9
T_7: 75% RDF + Rhizobium + MDSR14 + 12c (12c= *Burkholderia arboris*-High P solubilizing)	8.9	9.5	9.2	36.8	40.0	38.4	74.6	78.5	76.6
S.Em±	0.37	0.29	0.23	1.11	1.48	1.02	2.91	2.96	2.06
C.D at 5%	1.14	0.90	0.71	3.43	4.55	3.14	8.96	9.11	6.34

Table 2: Effect of novel bioformulations on number of nodules per plant, fresh and dry weight of nodules at R2 stage of soybean.

Treatments	Nodule number of per plant			Fresh weight of nodule (g)			Dry weight of nodule (mg)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1: Control	10.7	11.6	11.1	0.93	0.97	0.95	66.0	66.0	66.0
T_2: RDF only	20.0	19.0	19.5	1.80	1.78	1.79	79.3	77.0	78.2
T_3: 75% RDF	16.0	16.0	16.0	1.00	1.00	1.00	71.7	70.0	70.8
T_4: 75% RDF + Bio Zn	16.3	18.4	17.3	1.30	1.49	1.40	73.7	71.0	72.4
T_5: 75% RDF + Bio NPK	18.3	14.9	16.6	1.59	1.49	1.54	74.7	73.5	74.1
T_6: 75% RDF + Bio Zn + Bio NPK	19.7	18.2	19.0	1.63	1.60	1.62	76.0	76.0	76.0
T_7: 75% RDF + Rhizobium + MDSR14 + 12c (12c= *Burkholderia arboris*-High P solubilizing)	24.3	22.8	23.6	1.93	2.00	1.96	81.7	86.4	84.0
S.Em±	1.03	0.63	0.53	2819	0.06	0.05	2.36	3.17	2.27
C.D at 5%	3.18	1.94	1.63	8685	0.20	0.16	7.28	9.76	6.99

Note: R2: Full blooming stage.

seed index (14.41 g) was observed with 100% RDF alone (T_2), however, it was on par with 75% RDF + *Rhizobium* + MDSR14 + 12c (61.6 and 14.19 g, respectively). Whereas, significantly lower number of pods per plant (50.5) and seed index (12.07 g) recorded in control (T_1). The higher yield parameters which might be due to balanced application of inorganic fertilizer along with biofertilizers helped in slow and steady rate of nutrient release into soil solution to match the required absorption pattern of soybean thereby increase yield parameters. Results are in close conformity with Ekta Joshi *et al*. (2018) and Navasare *et al*. (2019).

Bioformulations on yield of soybean

Soybean seed yield, straw yield and biological yield as influenced by novel bioformulations during 2021-22, 2022-23 and pooled data is presented in Table 4. The pooled data of two years indicated that, significantly higher seed yield (2797 kg ha^{-1}), straw yield (4330 kg ha^{-1}) and biological yield (7077 kg ha^{-1}) was recorded with application of 100% RDF alone (T_2), however, it was on par with 75% RDF + *Rhizobium* + MDSR14 + 12c (2631, 4170 and 6786 kg ha^{-1}, respectively) (T_7) and (T_6). Whereas, significantly lower seed yield (2272 kg ha^{-1}), straw yield (3756 kg ha^{-1}) and biological yield (6028 kg ha^{-1}) recorded in control (T_1). The similar trend was noticed during 2021-22 and 2022-23. The increase in seed yield by 15.80 per cent was recorded with 75% RDF + *Rhizobium* + MDSR14 + 12c (T_2) over the control. Increase in yields was the result of balanced nutrition and favorable soil environment which promoted better assimilation leading to profuse growth and ultimately better yields. This might be due to cumulative effect of NPK fertilizer along with biofertilizers helped in slow and steady rate of nutrient release into soil solution to match the required absorption pattern of soybean thereby increase yield. Results are in close conformity with Ekta Joshi *et al*. (2018) and Jaga and Sharma (2015) reported that, higher yield in soybean by 75 per cent NPK + VAM + *Rhizobium* + PSB. Further Navasare *et al*. (2019) noticed in soybean.

Table 3: Effect of novel bio formulations on number of nodules per plant, fresh and dry weight of nodules at R5 stage of soybean.

Treatments	Nodule number per plant			Fresh weight of nodule (g)			Dry weight of nodule (mg)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1: Control	33.7	32.0	32.8	1.7	1.4	1.5	94.0	90.0	92.0
T_2: RDF only	42.0	43.1	42.5	2.3	2.7	2.5	112.3	114.5	113.4
T_3: 75% RDF	36.3	35.2	35.7	1.8	1.6	1.7	100.3	96.0	98.2
T_4: 75% RDF + Bio Zn	37.7	38.0	37.8	1.9	1.8	1.9	102.7	99.8	101.2
T_5: 75% RDF + Bio NPK	38.3	40.0	39.2	2.0	2.0	2.0	107.7	100.4	104.1
T_6: 75% RDF + Bio Zn + Bio NPK	39.3	42.0	40.7	2.2	2.0	2.1	109.3	103.6	106.4
T_7: 75% RDF + Rhizobium + MDSR14 + 12c (12c= *Burkholderia arboris*-High P solubilizing)	43.7	48.4	46.0	2.8	3.3	3.1	105.0	109.0	107.0
S.Em±	1.55	1.72	0.87	0.09	0.08	0.06	3.37	4.37	2.47
C.D at 5%	4.78	5.31	2.68	0.27	0.24	0.18	10.39	13.47	7.61

Note: R5: Initial seed filling stage.

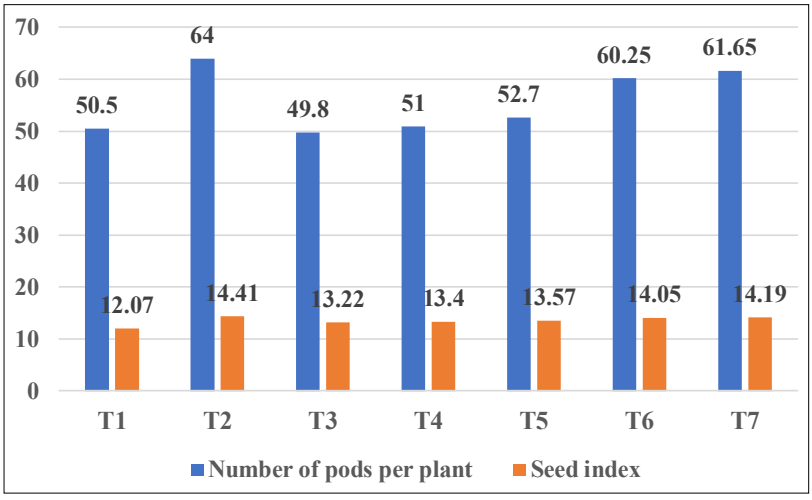

Fig 1: Effect of novel bioformulations on number of pods per plant and seed index of soybean (Pooled data of two years).

Bioformulations on seed quality

Significantly higher oil content (19.4%) and protein content (38.4%) was observed with 100% RDF alone (T_2), however, it was on par with 75% RDF + *Rhizobium* + MDSR14 + 12c (19.3 and 38.3%, respectively) (T_7) as compared to other treatment. Whereas, significantly lower oil content (17.2%) and protein content (36.1%) recorded in control (T_1) on pooled basis (Fig 2). the higher oil and protein content which might be due to better availability of required nutrients in the *rhizosphere* resulting increases the synthesis of amino acid *i.e*., cysteine, cysteine and methionine. Similar findings were also reported by Devi *et al.* (2013) and Morya *et al.* (2018) in soybean.

Bioformulations on major and micro nutrient uptake

The major and micro nutrients uptake by soybean crop are presented in Fig 3 and 4. The pooled data of two years indicated that, significantly higher uptake of nitrogen (103.74 kg ha^{-1}), phosphorus (17.54 kg ha^{-1}) potassium (91.40 kg ha^{-1}), zinc (1552.7 g ha^{-1}) and iron (3840 g ha^{-1}) uptake was recorded with 100% RDF alone (T_2), however, it was on par with 75% RDF + *Rhizobium* + MDSR14 + 12c (100.12, 16.73, 86.64, 1502 and 3643.3 g ha^{-1}, respectively) (T_7) and Whereas, significantly lower uptake of nitrogen (81.75 kg ha^{-1}), phosphorus (11.90 kg ha^{-1}) potassium (69.56 kg ha^{-1}) zinc (998.1 g ha^{-1}) and iron (1844.6 g ha^{-1}) was recorded in control (T_1). The higher nutrients uptake by crop which might be due inorganic fertilizers offer nutrients to the plant which are readily soluble in soil solution and thereby instantly available to the plants. These results were conformity with Devi *et al.* (2013) and Verma *et al.* (2017). Great availability of nutrients with the combined application of inorganic source and biofertilizers or inoculants seems to have promoted various physiological activities of plant thus growth and development of the plant resulted in higher uptake by the crop. These findings corroborate with those of Shubhangi *et al.* (2008) in soybean and Bhat *et al.* (2013) in field pea and Dipak *et al.* (2018) in soybean.

Bioformulations on major and micro nutrient availability after harvest

The pooled data of two years indicated that, significantly lower available nitrogen (190.20 kg ha^{-1}), phosphorus (12.93 kg ha^{-1}) potassium (283.20 kg ha^{-1}), zinc (0.258 mg kg^{-1}) and iron (8.11 mg kg^{-1}) was recorded with application of 100% RDF alone (T_2), as compared to other treatments. Whereas, significantly higher availability of nitrogen (280.7 kg ha^{-1}), phosphorus (21.2 kg ha^{-1}) potassium (362.8 kg ha^{-1}) zinc (1.0 mg kg^{-1}) and iron (10.19 mg kg^{-1}) was recorded in control (T_1) are presented in Fig 5 and 6. The lower nutrient availability in 100 per cent RDF alone (T_2), which might be due to higher uptake by the crop resulted in higher dry matter production and yield. Further, increase in nutrients uptake by application of RDF, Bio-NPK, Bio-Zn and inoculation of *Rhizobium* + MDSR14 + 12c together with the higher yield which ultimately leads to higher

Table 4: Effect of novel bio formulations on seed yield, straw yield, biological yield and harvest of soybean.

Treatments	Seed yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Biological yield (kg ha^{-1})			Harvest index		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1: Control	2197	2347	2272	3516	3996	3756	5713	6343	6028	0.38	0.37	0.38
T_2: RDF only	2756	2838	2797	4324	4357	4340	7026	7128	7077	0.38	0.39	0.39
T_3: 75% RDF	2341	2499	2420	3778	4065	3922	6139	6564	6352	0.38	0.38	0.38
T_4: 75% RDF + Bio Zn	2409	2599	2504	3967	4077	4022	6351	6676	6514	0.38	0.39	0.39
T_5: 75% RDF + Bio NPK	2427	2642	2535	3995	4150	4072	6357	6686	6522	0.38	0.39	0.39
T_6: 75% RDF + Bio Zn + Bio NPK	2534	2656	2595	4054	4154	4104	6588	6810	6699	0.38	0.39	0.39
T_7: 75 % RDF + Rhizobium + MDSR14 + 12c (12c= *Burkholderia arboris*-High P solubilizing)	2563	2699	2631	4100	4240	4170	6663	6909	6786	0.38	0.39	0.39
S.Em±	83.40	60.37	66.01	133.38	47.92	69.52	216.74	143.16	133.58	0.02	0.01	0.01
C.D at 5%	256.99	186.03	203.39	410.98	147.67	214.23	667.85	441.12	411.59	NS	NS	NS

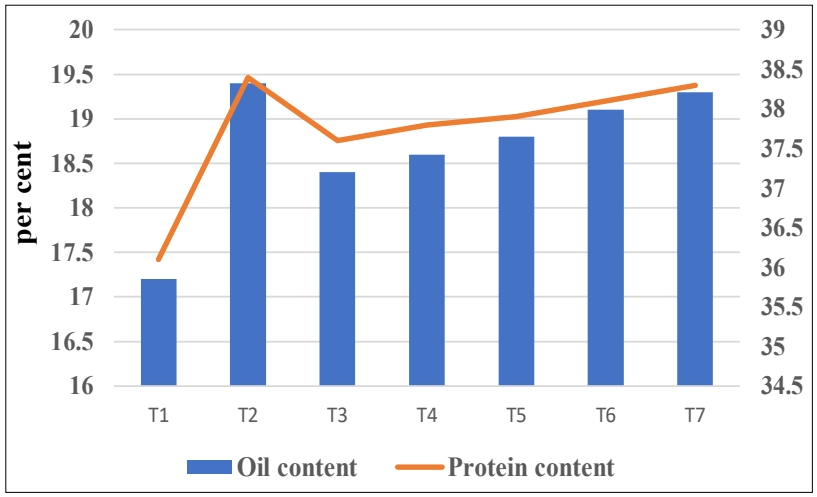

Fig 2: Effect of novel bioformulations on oil and protein content of soybean (Pooled data of two years).

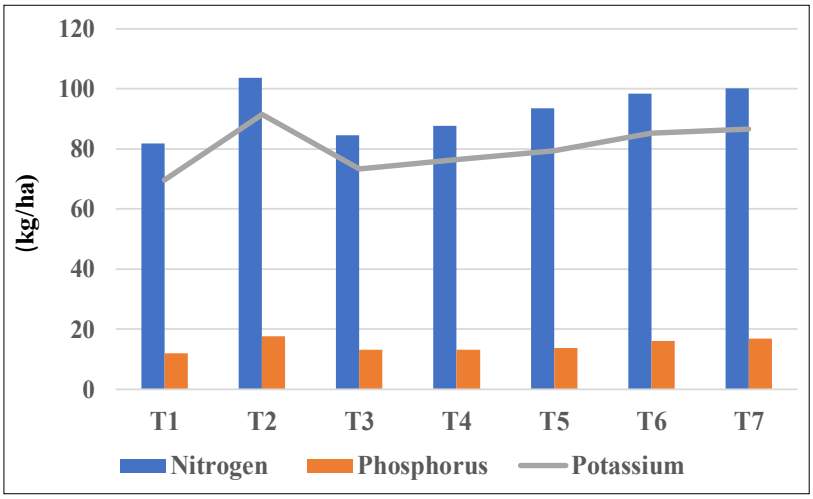

Fig 3: Major nutrients uptake by soybean crop as influenced by novel bioformulations (Pooled data of two years).

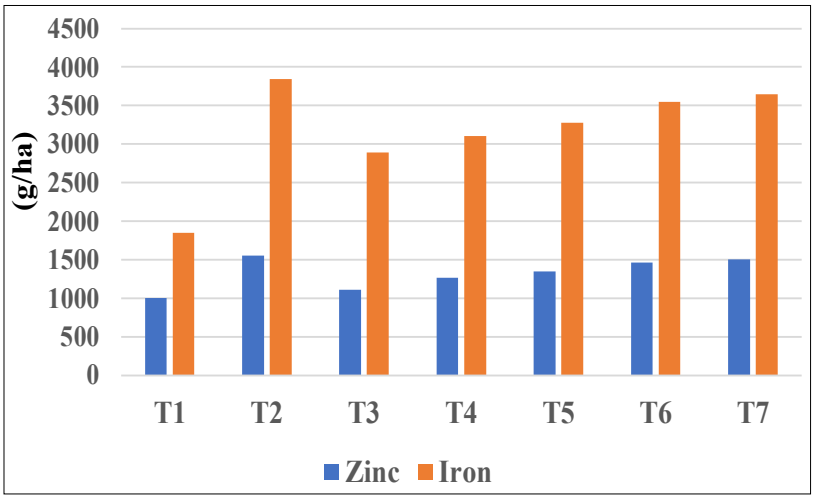

Fig 4: Micronutrient uptake by soybean crop as influenced by novel bioformulations (Pooled data of two years).

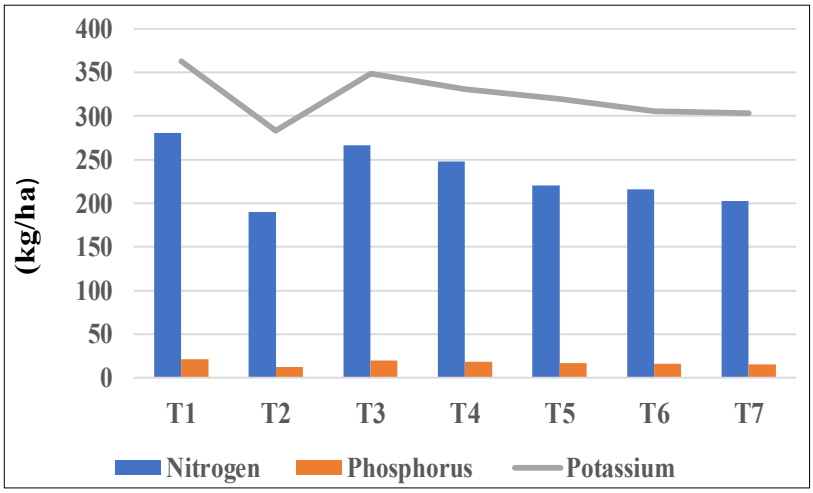

Fig 5: Novel bioformulations on major nutrient availability after harvest of crop (Pooled data of two years).

Fig 6: Novel bioformulations on micro nutrient availability after harvest of crop (Pooled data of two years).

Table 5: Effect of novel bio formulations on gross returns, net returns and benefit cost ratio of soybean.

Treatments	Gross returns (Rs ha^{-1})			Net returns (Rs ha^{-1})			BC ratio		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1: Control	120856	126738	123797	86293	90075	88184	3.50	3.46	3.48
T_2: RDF only	151598	153252	152425	112931	112985	112958	3.92	3.81	3.86
T_3: 75% RDF	128773	134946	131860	99758	104496	102127	4.44	4.43	4.43
T_4: 75% RDF + Bio Zn	132513	139346	135929	103448	107240	105344	4.56	4.24	4.40
T_5: 75% RDF + Bio NPK	133485	139538	136512	103667	110718	107193	4.58	4.47	4.52
T_6: 75% RDF + Bio Zn + Bio NPK	139360	143424	141392	110197	108818	109508	4.78	4.14	4.46
T_7: 75% RDF + Rhizobium + MDSR14 + 12c (12c= *Burkholderia arboris*-High P solubilizing)	140955	145746	143350	111784	114246	113015	4.83	4.63	4.73
S. Em±	4587	4449	3386	2819	4449	3249	0.23	0.13	0.16
C.D at 5%	14134	13710	10432	8685	13710	10010	0.70	0.41	0.50

nutrients availability in the soil. It was also found that application of Bio-NPK and Bio-Zn have influenced the population of bacteria, N-fixers, P-solubilizers, K solubilizers and Zinc-solubilizers and iron in the soil which increased the nutrients availability in soil. Similar results were also reported by Jaga and Sharma (2015) noticed that, integrated use of chemical fertilizer and co-inoculation of VAM, *Rhizobium* and PSB can be used to boost up the production of soybean crop and saves approximately 25 per cent inorganic fertilizers further also reported by Leite *et al.* (2019) and Meena *et al.* (2021) in soybean.

Bioformulations on economics

The perusal of pooled data of two years presented in Table 5 revealed that, significantly higher net returns (Rs.1,13,015 ha^{-1}) and benefit cost ratio (4.73) was recorded with application of 75% RDF + *Rhizobium* + MDSR14 + 12c followed by next best treatment was T_6 and T_2. Whereas, significantly lower net returns (Rs. 88,184 ha^{-1}) and benefit cost ratio (3.46) was recorded in control (T_1). The higher net returns and benefit cost ratio which might be due to higher yield. The similar results were close conformity with findings of Sarawgi *et al.* (2012) also reported higher profit with the application of chemical fertilizers along with biofertilizers and further also reported by Jaga and Sharma (2015) in soybean by 75% NPK + VAM + *Rhizobium* + *PSB*.

CONCLUSION

The present investigation concluded that, pooled data of two years, it can be inferred that, application of 75 per cent RDF + *Rhizobium* + MDSR14 + 12c can be recommended for economically viable, eco-friendly, environmentally sound and sustainability in nature, besides improving the physico chemical properties of soil and in turn higher growth, productivity and profitability of soybean under medium deep black soil in Northern Transition Zone of Karnataka (India).

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Conflict of interest

All authors declare that they have no conflicts of interest.

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