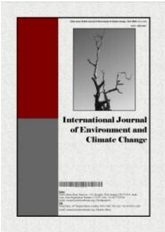

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Performance of Gluconate and Lactate Based Formulations on Plant Growth and Yield Attributes in Maize (*Zea mays* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To check the efficacy of gluconate and lactate based formulations on plant growth and yield characteristics of maize.
Place and Duration of Study: School of Agricultural Sciences, Malla Reddy University, Hyderabad, spring 2021.
Methodology: The experiment was laid-out in Randomized Block Design (RBD), with Maize hybrid (DHM-117) spacing adopted (60 x 20 cm) with 4 replications. The treatments *viz*; T_1: Control (No fertilizer), T_2:100% RDF, T_3: 75% RDF + 25% Sahasra Organic Formulations (SOF), T_4:50% RDF + 50% SOF, T_5: 25% RDF + 75% SOF, T_6: 100% SOF. The RDF (N:72-80; P:24; K:20 kg/acre).
Results: The yield attributes were recorded intermittently and maximum grain yield (7,649.8 kg ha^{-1}) and Stover yield (8,859.87 kg ha^{-1}) were recorded with T_2 (100% RDF), followed by T_3 (75% RDF + 25% Sahasra Organic Formulations). Similarly gross returns (₹ 123606.5 ha^{-1}), net returns (₹ 87116.49 ha^{-1}) and B: C (3.4) ratio was also recorded highest in T_2 followed by T_3 (75% RDF + 25 % SOF), while the lowest were recorded with T_1 (control).
Conclusion: Adoption of gluconate and lactate based formulations enhanced soil fertility, soil organic carbon and yield in Maize crop. The study concluded that the integrated approach *i.e.*, T_3

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(75% RDF + 25% SOF) has realized the highest net returns (₹ 82466.8 ha^{-1}) and B: C ratio (3.4) in comparison to the 100% RDF treatment thus reducing the cost of fertilizers and benefiting the net returns to the farmers.

Keywords: Gluconate; lactate; innovative technologies; soil fertility; net returns.

1. INTRODUCTION

Maize is grown almost all over the world in different agro-climatic conditions and different seasons. It is the third most important food crop next to rice and wheat. It is also known as the miracle crop or queen of cereals due to its high productivity potential among the cereal crops of the Graminaceae family. In India, maize is not only grown for food and fodder but also several industrial uses and acquired a dominant role in the farming sector and macro-economy of the Asian region [1]. Furthermore, one of the most critical elements influencing maize crop development and yield productivity is fertilizer management [2]. The current NPK fertilizer consumption ratio is 10: 2.9: 1 against the optimal ratio of 4: 2: 1 [3]. Maize area and production have steadily increased in India during the past two decades and it is cultivated in an area of 9.2 M ha with an average production of 28.7 Mt and productivity of 3115 kg ha^{-1}. This non-judicious nutrient application by farmers causes multi-nutrient deficiencies. In this context, the smart use of integrated nutrient management and use of organic formulations is one of the greatest options for ensuring long-term crop productivity, while maintaining soil fertility in maize and other cereal-based cropping systems. This ultimately improves crop yield [4]. Cultivation of maize in the spring season is a common practice in Peninsular India (Telangana, Andhra Pradesh, Karnataka and Tamil Nadu) as well as in North Eastern plains, where the winter remains frost free and the temperature does not fall below 12˚C [5].

1.1 Gluconic Acid Based Formulations

Among various organic acids, gluconic acid seems to be the major mechanism of phosphate solubilization by gram negative bacteria [6]. Gluconic acid is produced by the oxidative metabolism of glucose dehydrogenase enzyme through microbial fermentation with different types of *Aspergillus niger* strains [7].

1.2 Lactic Acid Based Formulations

Different strains of *Lactobacillus* are used for Lactic acid production. Lactic acid bacteria have also been used for the treatment of animal manures, farm yard manure and sewage for odor abatement and as an inoculant to accelerate the composting of organic wastes [8].

1.3 Amino Acids Based Formulations

The chelating ability of amino acids has been used in fertilizers for agriculture to facilitate the delivery of minerals to plants to correct mineral deficiencies, such as iron chlorosis and other nutrient deficiencies. These fertilizers are also used to prevent deficiencies from occurring and improve the overall health of the plants. Amino acids can be extracted from marine algae like seaweeds (*Ascophyllum nodosum*), plants like soybean, maize gluten, protein cake from vegetable oil industries and animal proteins [9].

1.4 Protein Lacto Gluconate Nutrients

Several organic carbon (OC) rich formulations tailored with amino acids, gluconic and lactic acids blended with elemental Nitrogen (N), phosphorous (P), potassium (K), sulfur (S), calcium (Ca), magnesium (Mg), boron (B), copper (Cu), iron (Fe), molybdenum (Mo), manganese (Mn) etc., were produced from research & development based biotech industries. These formulations were proved through bio-efficacy studies by several national and international agriculture universities and research laboratories on various crop systems and environmental conditions [10].

2. MATERIALS AND METHODS

2.1 Preamble

The experiment will be conducted to study the efficacy of integrated usage of the recommended dose of fertilizers (N:72-80; P:24 K:20 kg/acre) and Lactate, Gluconate based organic formulations on Maize. The study will focus on growth and development in terms of plant growth and yield attributes.

2.2 Location

The experimental site Malla Reddy University is situated in Southern Telangana Agro Climatic

Zone at longitude - 78° 46′ 22.69″ E (78.772971), latitude - 17° 21′ 9.86″ N (17.352743) with an altitude of 547 meters above Mean Sea Level (Fig. 1).

2.3 Crop and Variety

Maize variety, DHM-117 a short duration high yielding genotype suitable for *kharif* and *rabi* seasons was used for the field experiment.

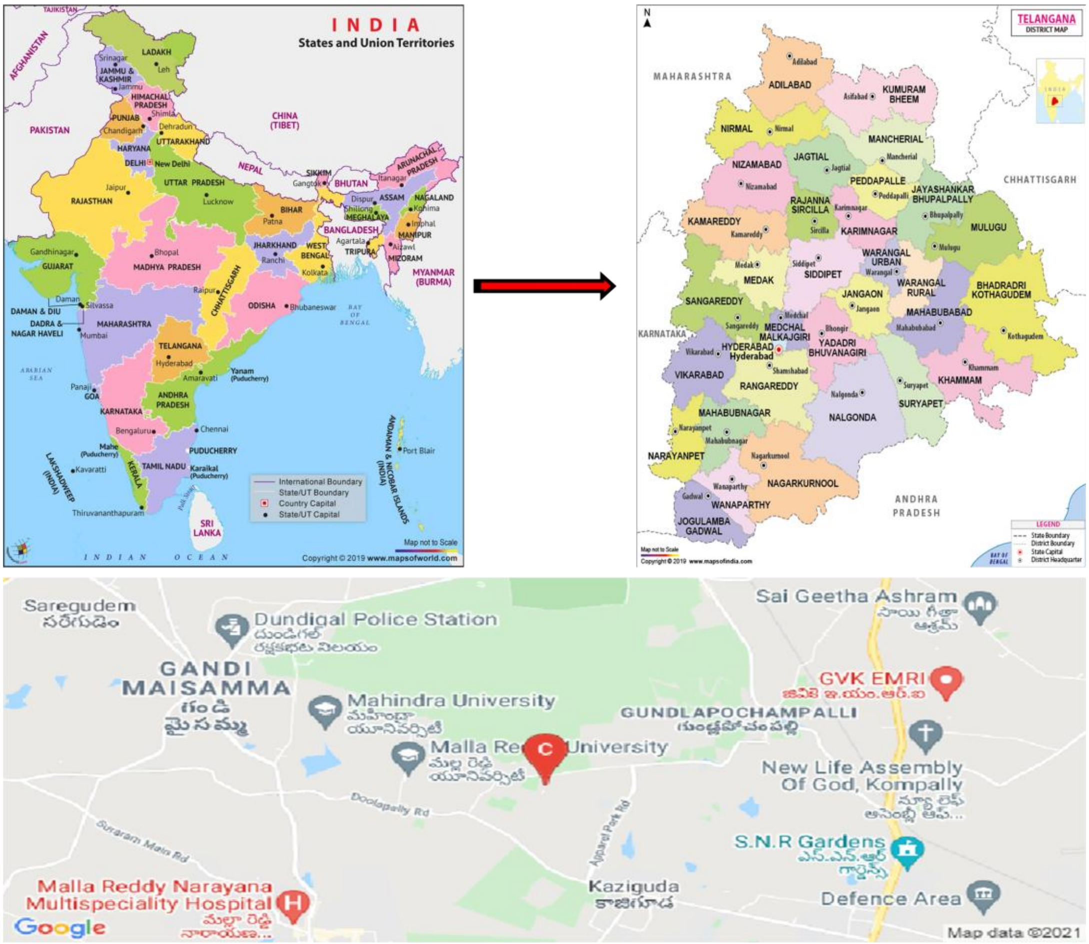

Fig. 1. Current location map of the field experiment

2.4 Experimental Details

Table 1. Experimental details of maize crop

S.No.	Particulars	Details
1.	Year of Experiment	2021-22
2.	Crop	Maize
3.	No. of Treatments	6
4.	No. of Replications	4
5.	Spacing	60×20 cm
6.	Experimental Design	Randomized Block Design
7.	Season	*spring* -2021
8.	Variety	DHM-117
9.	Location	Malla Reddy University, Telangana

Treatments Details: T_1: Control (No fertilizer); T_2: 100% RDF; T_3: 75% RDF + 25% Sahasra Organic Formulations; T_4: 50% RDF + 50% Sahasra Organic Formulations; T_5: 25% RDF + 75% Sahasra Organic Formulations; T_6: 100% Sahasra Organic Formulations; Recommended Dose of Fertilizer (kg/acre) N: 72-80; P: 24; K: 20

2.5 Sahasra Organic Products

Sahasra organic products i.e., Organic manure, Sage, Nutri and Poshak were formulated and supplied by Sahasra crop science, Hyderabad for testing the efficacy of the products for improving the soil health and yield.

Crop raised as per recommended package of practices of the University. All the recommended agronomic practices are uniformly followed for all treatments viz; hoeing, intercultural operations, weedicides application and irrigations. The soil physico chemical characteristics, microbial characteristics, plant growth parameters, yield attributes and post harvest parameters [10]. For data recording five sample plants and cobs were identified randomly collected and stacked separately for sun drying and various observations for treatment evaluation were recorded as per the experimental design. The data were statistically analyzed by standard tools for interpretation of the results. Data recorded from the experimental identified plants in each sub-plot were randomly selected and taken the average weight of all the cobs weight per plant^{-1}, no.of cobs per plant, cob length (cm), cob girth (cm), No. of kernels cob^{-1}, grain (kg ha^{-1}) and stover yield (kg ha^{-1}).

2.6 Grain Yield

The grain yield was noted by weighing the grains shelled from the cobs obtained from the central four rows of each sub-plot and converting it into kg ha^{-1}.

2.7 Biological Yield

It was recorded by weighing the sun dried plants along with ears obtained from central four rows of each sub-plot. The biological yield thus obtained in each sub-plot was converted into kg ha^{-1}.

2.8 Harvest Index (%)

HI (%) = Grain yield/Biological yield x 100 [11]

2.9 Statistical Analysis

The data obtained from the field experiment was subjected to statistical analysis. Wherever the treatments difference were significant, Critical differences were worked out at a 0.05 per cent probability level and the values were furnished [12]. The treatment differences that were not significant at five per cent were denoted as “NS”. A brief interpretation of the results was given at the end of each parameter.

3. RESULTS AND DISCUSSION

3.1 Plant Height (cm)

It is evident from (Table 3 and Fig. 2) that the increased plant height among all the treatments in the 6th leaf stage was observed in T_2 (100% RDF) 45.8 cm, T_3 (75% RDF + 25% Sahasra Organic Formulations) 172.2 cm on silking stage, T_2 (100% RDF) 108.4 cm on dough stage and in T_3 (75% RDF + 25% Sahasra Organic Formulations) 185.6 cm at maturity stage.

3.2 Number of Cobs Per Plant

It is clear from (Table 4.) that the cob-bearing capacity is one of the most important crops yield components. More or less cobs, it is the genetic character of any cultivar but some improvement can be expected owing to agronomic manipulations. The number of cobs per plant was not affected significantly by different treatment combinations. The highest number of cobs per plant was observed with the recommended dose of fertilizer treatment (T_2).

Table 2. Details of sahasra organic formulations

S.No.	Crop	Product	Dosage	Time of Application	Spraying Intervals
1.	Maize	Organic Manure	50 kg/acre	Basal Dose (Before sowing)	Single Dose
		Sage	3 ml/lit	20, 40, 60 DAS	Three Sprays
		Poshak	3 ml/lit	30 & 40 DAS	Two Sprays
		Nutri	2 ml/lit	20 & 40 DAS	Two Sprays

**Coragen 10 DAS (for fall army warm)*
Spraying Schedule: 20, 40 & 60 Days After Sowing
Note: Organic Manure (50 kg/acre as Basal Application); Sage (3 ml/lit at 20-40-60 DAS); Nutri (2 ml/lit at 20 & 40 DAS); Poshak (3 ml/lit at 30 & 40 DAS); If micronutrient deficiency observed on leaves additional spray can be given

Table 3. Plant height of maize crop under different stages of crop growth

Plant height (cm)	6^{th} Leaf	Silk stage	Dough stage	Maturity
T_1	34.1	130.8	82.4	142.6
T_2	45.8	171.1	108.4	178.1
T_3	42.6	172.2	107.4	185.6
T_4	40.3	160.1	100.2	165.4
T_5	38.1	143.9	91.0	158.1
T_6	37.7	138.9	88.3	149.8
C.D.	**1.755**	**6.850**	**5.286**	**17.476**
SE(m)	0.577	2.252	1.738	5.475
SE(d)	0.816	3.185	2.458	7.743
C.V.	**2.904**	**2.947**	**2.171**	**5.675**

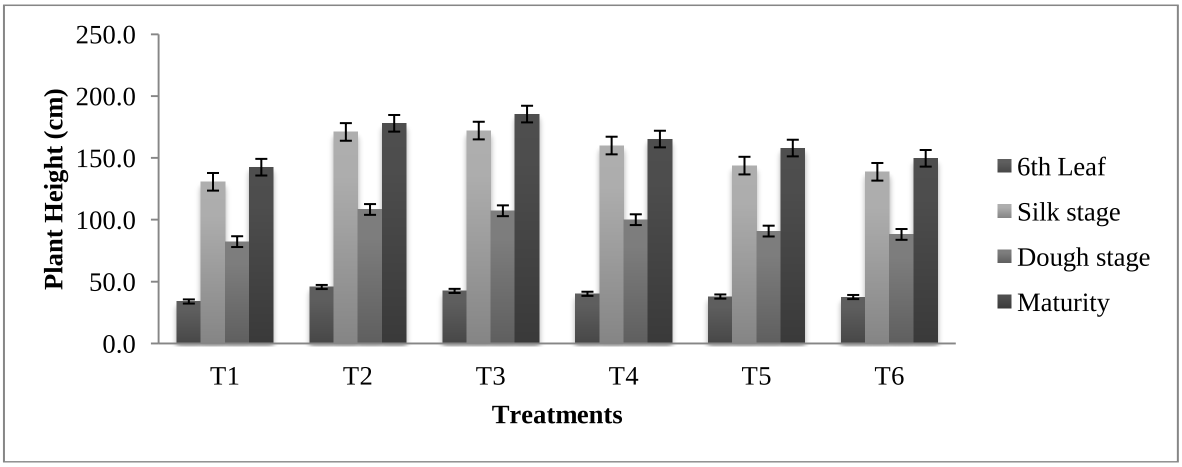

Fig. 2. Plant height of maize crop under different stages of crop growth

3.3 Cob Length (cm)

As mentioned in (Table 4) that the highest cob length (20.7 cm) was recorded with T_3 (75% RDF + 25% SOF) followed by T_2 (100% RDF) *i.e* 19.8 cm, while the least cob length has been recorded in T_1 control (16.5 cm) treatment. An increase in cob length might be due to adequate and uniform availability of nutrients during the crop growth which resulted in enhancement of the yield attributes Pathak et al. [13] also observed similar results.

3.4 Cob Girth (cm)

It is evident from (Table 4) that the maximum cob girth (14.5 cm) was recorded with T_2 (100% RDF) followed by T_3 (75% RDF + 25% SOF) *i.e* 14.3 cm, while the least cob girth (11.7 cm) was recorded with T_1 (control).

3.5 Cob Weight (g)

The highest cob weight (180.6 g) was recorded with T_3 (75% RDF + 25% SOF) followed by T_2 (100% RDF) (175.9), while the lowest cob weight (128.3 g) was noted with T_1 (control).

3.6 Number of Kernels Cob^{-1}

The highest number of kernels per cob (554.6) was recorded with T_3 (75% RDF + 25% SOF) followed by T_2 (100% RDF) (550.7), while the lowest number of kernels per cob (457.4) was recorded with T_1 (control).

3.7 Grain Yield (kg ha^{-1})

Significantly higher grain yield (7649.8 kg ha^{-1}) was recorded with T_2 (100% RDF) which was statistically on par with T_3 (75% RDF + 25% SOF) (*i.e* 7241.3 kg ha^{-1}), followed by T_4 which recorded 7,019.9 kg ha^{-1} grain yield closely followed by T_5 and T_6 (6,763.6 and 6,179.1 kg ha^{-1} respectively), while significantly lower grain yield (4808.2 kg ha^{-1}) was recorded with T_1 (control). The maximum grain yield might be attributed due to the combined effect of fertilizer along with organic formulations which escalated the availability of nutrients and transport of major nutrients like N, P and K which also resulted in increased plant height, no.of leaves and leaf area which in turn lead to increased production and translocation of photosynthates and yield attributes like cob length (cm), cob girth (cm), number of rows cob^{-1}, cob weight (g), grain weight (g). The results are in a similar trend to the results of an increase in stover yield due to fertigation of microbes as reported by Abdelhamid et al. [14], Baral and Adhikari [15] and Meena et al. [16]. Sonawane et al. [17] also reported better grain and dry fodder yield with combined application of nutrients due to improvement in yield parameters of maize crops. Application of organic manures because of combination with inorganic fertilizers not only enhanced the nutrient supply for higher grain yield but also alters the soil physical and chemical properties which favor better crop growth and yield [18].

3.8 Stover Yield (kg ha^{-1})

Significantly higher stover yield (8859.8 kg ha^{-1}) was recorded with T_2 (100% RDF) which was statistically on par with T_3 (75% RDF + 25% SOF) which is (8850.6 kg ha^{-1}), followed by T_4, T_5, T_6 respectively (*i.e* 8394.9, 8252.7, 8049.3 kg ha^{-1}), while the lowest stover yield (7835.6 kg ha^{-1}) was recorded with T_1 (control). The increase in stover yield might be due to the combined effect of fertilizer along with organic formulations which enhanced the availability of nutrients like N, P and K, which increased plant biometric observations such as plant height, the number of leaves and leaf area which in turn lead to higher production and translocation of photosynthates and more dry matter production plant^{-1}. The results are in a similar trend were the increase of stover yield due to fertigation of microbes as reported by Abdelhamid et al. [14] through fertigation, by seed inoculation in maize by Baral and Adhikari [15] and Meena et al. [16]. Manjhi et al. [19] reported the maximum grain and stover yield under integrated treatment. Karki et al. [20] also recorded similar results in respect of grain and stover yield of maize.

3.9 Test Weight (g)

The highest test weight (31.8 g) was observed with T_3 (75% RDF + 25% SOF) which was on par with T_2 (100% RDF) (*i.e* 31.5 g) followed by T_4, T_5 and T_6 respectively (*i.e* 30.4, 30.4, 30.2 g), while the lowest test weight (29.1 g) was recorded with T_1 (control). Due to the application of organic formulations plants received maximum nutrients throughout their growth period and nourished sufficiently, which resulted in a maximum 100 kernel weight. Similar findings of more grain weight with imposing integrated treatment in Maize crop was reported by Cheema et al. [21].

3.10 Harvest Index (%)

A significantly more harvest index (46.34) was noted with T_2 (100% RDF) followed by T_3 (75% RDF + 25% SOF which is (45.54), while the lowest harvest index (38.03) was observed with T_1 (control).

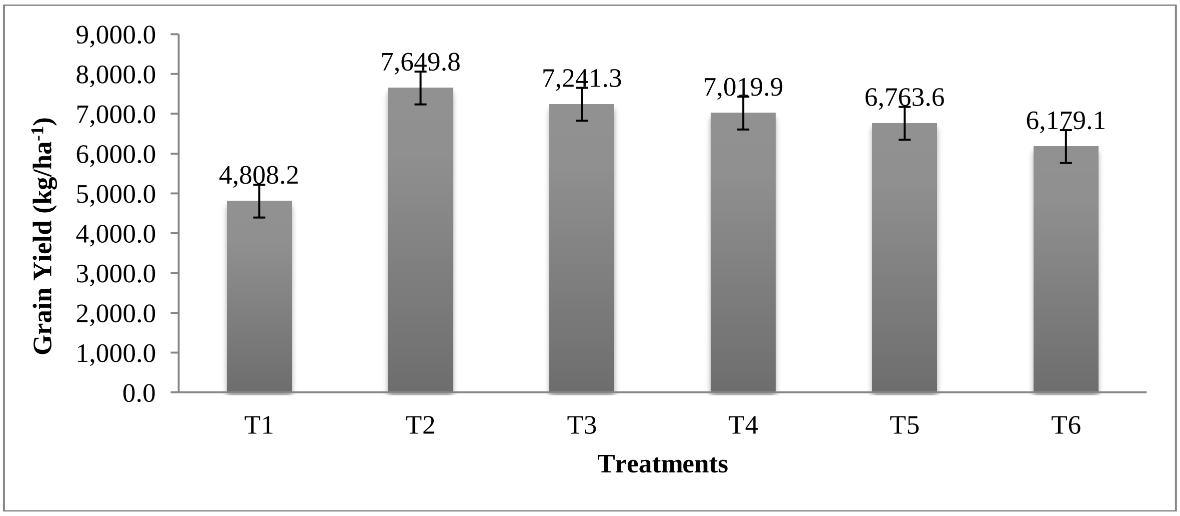

Fig. 3. Grain yield of maize as influenced by different doses of fertilizers and sahasra organic formulations

Table 4. Yield attributes of maize (*Zea mays* L.) as influenced by different doses of fertilizers and Sahasra Organic formulations.

Treatments	No.of Cobs/ plant	Cob length (cm)	Cob girth (cm)	Cob weight (g)	No. of Kernels/Cob	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Test weight (g)	Harvest Index (%)
T_1	9.6	16.5	11.7	128.3	457.4	4,808.2	7,835.60	29.1	38.03
T_2	11.9	19.8	14.5	175.9	550.7	7,649.8	8,859.87	31.5	46.34
T_3	11.8	20.7	14.3	180.6	554.6	7,241.3	8,850.63	31.8	45.00
T_4	10.4	18.8	13.9	167.6	526.3	7,019.9	8,394.90	30.4	45.54
T_5	10.2	18.0	13.2	157.3	509.1	6,763.6	8,252.73	30.4	45.04
T_6	10.4	16.9	12.1	142.2	494.2	6,179.1	8,049.30	30.2	43.43
SE.m±	**0.388**	**0.305**	**0.186**	**2.457**	**7.546**	**136.68**	**31.179**	**0.395**	**1.172**
CD (P=0.05)	**1.238**	**0.975**	**0.593**	**7.842**	**24.085**	**415.75**	**99.515**	**1.260**	**3.741**

T_1: Control (No fertilizer), T_2: 100% RDF, T_3: 75% RDF + 25% Sahasra Organic Formulations, T_4: 50% RDF + 50% Sahasra Organic Formulations, T_5: 25% RDF + 75% Sahasra Organic Formulations, T_6: 100% Sahasra Organic Formulations. Recommended Dose of Fertilizer (kg/acre) N: 72-80; P: 24 K: 20

Table 5. Economics of maize (*Zea mays* L.) as influenced by different doses of fertilizers and Sahasra organic formulations

Treatment	Gross returns	Net returns	B:C
T_1	79958.975	51308.98	2.8
T_2	123606.491	87116.49	3.4
T_3	117469.759	82466.76	3.4
T_4	113693.399	79477.40	3.3
T_5	109706.733	76627.73	3.3
T_6	100736.175	68811.18	3.2

Grain cost Rs 15 /kg; Stover cost = Rs 1/kg

From this study, application of integrated application of (75% RDF + 25% Sahasra Organic Formulations) was found to be on par with the 100% recommended dose of fertilizer was recorded with the highest grain yield (7649.8 kg ha^{-1}) and stover yield (8859.8 kg ha^{-1}), gross returns (₹ 123606.5 ha^{-1}), net returns (₹ 87116.49 ha^{-1}) with B: C ratio 3.4. and economical with the highest net returns (₹ 82466.8 ha^{-1}) and B: C ratio (3.4) in both the treatments as mentioned in Table 5.

4. CONCLUSION

From this study, it can be concluded that the application of recommended dosages of chemical fertilizers in combination with Sahasra organic nutrients (75% RDF + 25% Sahasra Organic Formulations) recorded higher yields. In addition to this, the application of Sahasra organic nutrients enhances soil health by reducing the cost of cultivation to the farmers in respect of total nitrogen, phosphorus and potassium content in the soil.

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ETHICAL APPROVAL

The authors declare that all the experiments were conducted according to the current laws of the country in which they were performed.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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