



# Response of Crop Growth and Yield to Long-term Fertilization and Manuring in Inceptisols of Western Maharashtra under a Soybean & Wheat Cropping System

C. Vairavan <sup>a\*</sup>, A.G. Durgude <sup>b</sup>, B.D. Bhakare <sup>c</sup>,  
B.M. Kamble <sup>a</sup>, U.S. Surve <sup>d</sup>, S.A. Kadam <sup>e</sup>  
and Cuba Perumal <sup>f</sup>

<sup>a</sup> Department of Soil Science, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India.

<sup>b</sup> AICRP on IWM, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India.

<sup>c</sup> KDSP College of Agriculture, Nashik, Maharashtra, India.

<sup>d</sup> Department of Agronomy, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India.

<sup>e</sup> Centre of Excellence on Digital Technologies for Smart and Precision Agriculture (CoE-DTSPA),  
Department of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra,  
India.

<sup>f</sup> International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Hyderabad, India.

## Authors' contributions

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

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\*Corresponding author: E-mail: [vairavanc99@gmail.com](mailto:vairavanc99@gmail.com), [k.c.vairavan@gmail.com](mailto:k.c.vairavan@gmail.com);

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## ABSTRACT

The present investigation was undertaken during the year 2023–24 (8<sup>th</sup> cycle) at the Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, to evaluate the long-term effects of integrated nutrient applications on a soybean–wheat in Inceptisol. The long-term field experiment was initiated with the objective of developing a suitable integrated nutrient supply and management system for sustaining productivity under this cropping system. The experimental layout followed a Randomized Block Design (RBD) with 12 treatments replicated four times. The treatments consisted of different levels of the Recommended Dose of Fertilizers (RDF) at 50%, 75%, and 100%, in combination with various organic inputs namely farmyard manure (FYM), wheat cut straw (WCS), and green manure (GM) applied during the Kharif season. In the Rabi season, only chemical fertilizers were applied at different RDF levels without organic amendments. Among the treatments, the application of 50% nitrogen through FYM along with 50% RDF during Kharif and 75% RDF during Rabi (T<sub>6</sub>) recorded significantly higher grain yields of soybean (3092 kg ha<sup>-1</sup>) and wheat (3535 kg ha<sup>-1</sup>). These yields were statistically at par with those obtained under T<sub>10</sub> (50% N through GM + 50% RDF) and T<sub>5</sub> (100% NPK). Furthermore, treatment T<sub>6</sub> also exhibited a significant positive influence on the growth and yield attributes of both soybean and wheat, indicating its effectiveness in enhancing crop performance in the Inceptisol soils of Western Maharashtra.

*Keywords:* INM; long-term fertilizer experiment; soybean-wheat cropping system; inceptisol.

## 1. INTRODUCTION

Sustainable crop production in intensive cropping systems requires a balanced and integrated approach to nutrient management (Tahat *et al.*, 2020). The soybean–wheat cropping sequence, widely practiced in the semi-arid regions of India, plays a crucial role in ensuring food and nutritional security. However, continuous reliance on chemical fertilizers alone has raised concerns about soil health degradation, declining factor productivity, and nutrient imbalances. In this context, integrated nutrient management (INM), which combines organic and inorganic sources of nutrients, has emerged as a promising strategy to sustain crop yields while improving soil quality over the long term (Castellini *et al.*, 2021).

To support this approach, organic inputs such as farmyard manure (FYM), wheat cut straw (WCS), and green manure (GM) as Daincha were selected due to their multiple benefits for soil health. These include improved soil structure, enhanced microbial activity, and the slow and sustained release of nutrients. Such inputs contribute significantly to building soil organic carbon, enhancing moisture retention, and promoting nutrient cycling, all of which are essential for maintaining long-term soil fertility (Bhattacharya *et al.*, 2016). Additionally, they are readily available as agricultural by-products, making them cost-effective and easily adoptable by farmers for integrated nutrient management.

The Inceptisol of Western Maharashtra, characterized by moderate fertility and coarse texture, require location-specific and long-term nutrient strategies to ensure sustainable productivity. In response to this need, Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, has been conducting long-term fertility experiments (LTFEs) to evaluate the effects of organic and inorganic nutrient sources on soil and crop performance. The present investigation was undertaken within this framework to assess the combined impact of organic inputs namely FYM, WCS, and GM and varying levels of the Recommended Dose of Fertilizers (RDF) on the productivity of soybean and wheat under an established long-term field experiment.

## 2. MATERIALS AND METHODS

The integrated nutrient management experiment at Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, Maharashtra, was initiated as a long-term field trial during the 2016–17 cropping cycle under a soybean–wheat cropping system. The study was laid out in a RBD with 12 treatments (Table 1.) and four replications. The experimental soil belongs to the Inceptisol order and is classified under the family *Fluventic Haplustepts*. The long-term field experiment at Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, was originally initiated in 1984 on the same experimental field under a sorghum–wheat cropping system, employing the same set of treatments. In the year 2016–17, the cropping sequence was transitioned to soybean–wheat,

while retaining the original treatment structure and experimental layout to ensure continuity in long-term assessment. Table 2 presents the initial soil properties of the experimental field as recorded in 1984 at the start of the long-term trial.

The experimental field is situated at 19°36'N latitude and 74°64'E longitude, at an elevation of approximately 495 meters above mean sea level. Agro-climatically, the site falls under the semi-arid zone, characterized by hot and dry summers and cool to mild winters.

The organic treatments included farmyard manure (FYM), wheat cut straw (WCS), and green manure in the form of *Dhaincha* (loopings), which were used to substitute 25%

and 50% of the recommended nitrogen levels. Nitrogen was applied in two equal splits for both soybean and wheat crops—half at the time of sowing and the remaining half at 30 days after sowing. The organic inputs (FYM, WCS, and *Dhaincha* loopings) were incorporated into the soil during the summer season prior to ploughing, ensuring adequate decomposition and nutrient release before crop establishment.

## 2.1 Statistical Analysis

The analysis of variance for the data on growth and yield with significance level  $P = .05$  was done with AGRES software. The least square different (LSD) was used to separate the significantly differed mean.

**Table 1. Treatments details of INM experiment, MPKV, Rahuri**

Tr. No.	Kharif (Soybean)	Rabi (Wheat)
T <sub>1</sub>	Control	Control
T <sub>2</sub>	50% RDF	50% RDF
T <sub>3</sub>	50% RDF	100% RDF
T <sub>4</sub>	75% RDF	75% RDF
T <sub>5</sub>	100% RDF	100% RDF
T <sub>6</sub>	50% N (FYM) + 50% RDF	75% RDF
T <sub>7</sub>	25% N (FYM) + 75% RDF	50% RDF
T <sub>8</sub>	50% N (WCS) + 50% RDF	75% RDF
T <sub>9</sub>	25% N (WCS) + 75% RDF	50% RDF
T <sub>10</sub>	50% N (GM) + 50% RDF	75% RDF
T <sub>11</sub>	25% N (GM) + 75% RDF	50% RDF
T <sub>12</sub>	Farmer's Practice (Urea @ 50 kg ha <sup>-1</sup> )	Farmer's Practice (Urea @ 50 kg ha <sup>-1</sup> )

Note: RDF (N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O kg ha<sup>-1</sup>) a) Soybean; 50:75:45 b) Wheat; 120:60:40

**Table 2. Initial soil properties of INM experimental soil during 1984**

Parameters	Values
Coarse sand (%)	6.50
Fine sand (%)	15.8
Silt (%)	26.6
Clay (%)	51.1
Textural class	Clay
Bulk density (Mg m <sup>-3</sup> )	1.32
pH (1:2.5)	8.2
EC (1:2.5 dS m <sup>-1</sup> )	0.27
Organic carbon (g kg <sup>-1</sup> )	6.40
Available N (kg ha <sup>-1</sup> )	153
Available P (kg ha <sup>-1</sup> )	14.2
Available K (kg ha <sup>-1</sup> )	705
Fe (mg kg <sup>-1</sup> )	12.9
Mn (mg kg <sup>-1</sup> )	22.1
Zn (mg kg <sup>-1</sup> )	0.87
Cu (mg kg <sup>-1</sup> )	3.27

### 3. RESULTS AND DISCUSSION

#### 3.1 Effect of INM on Growth and Yield Attributes of Soybean

Application of different nutrient management practices at MPKV, Rahuri had a significant impact on the growth and yield attributes of soybean, namely plant height, number of branches per plant, number of leaves per plant, leaf area, and number of root nodules. Combined application of organic and inorganic fertilizers recorded higher growth and yield attributes. Similar results were reported by (Surve et al., 2019) and (Choudhary et al., 2021).

##### 3.1.1 Plant height

The plant height varied significantly among the treatments. Highest plant height (88.34 cm) recorded in T<sub>6</sub> (50% N through FYM + 50% RDF during *Kharif* and 75% RDF during *Rabi*) which was on par with treatments T<sub>10</sub> – 50% N through GM and 50% N through RDF during *Kharif* and 75% RDF during *Rabi* (85.72 cm) and T<sub>5</sub> (100% RDF – 83.43 cm). Control (T<sub>1</sub>) (64.34 cm) recorded lowest plant height. The superior plant height under T<sub>6</sub> and T<sub>10</sub> can be attributed to the combined effect of organic and inorganic nutrient sources, which likely enhanced nutrient availability throughout the crop growth stages through improved microbial activity and better root development. The inorganic alone (100% RDF) recorded comparable plant height as it makes slightly higher nutrients availability.

##### 3.1.2 Number of branches per plant

The number of branches per plant increased with improved nutrient supply. The highest number of branches (4.8) was recorded in T<sub>6</sub> (50% N through FYM + 50% RDF during *Kharif* and 75% RDF during *Rabi*) which statistically at par with T<sub>10</sub> (50% N through GM + 50% RDF during *Kharif* and 75% RDF during *Rabi*) (4.6) and T<sub>5</sub> (100% RDF) (4.5), while the control (T<sub>1</sub>) recorded significantly fewer branches (2.4). Increased branching under integrated nutrient management can be linked to a balanced and sustained nutrient supply through FYM and GM that promotes vegetative growth and shoot differentiation.

##### 3.1.3 Number of leaves per plant

Application of 50% N through FYM + 50% RDF during *Kharif* and 75% RDF during *Rabi* (T<sub>6</sub>)

recorded higher no. of leaves per plant (14.8), which was statistically at par with T<sub>10</sub> (50% N through GM + 50% RDF) (14.6), and T<sub>5</sub> (100% RDF) (14.6) recorded the maximum leaf numbers, whereas the control (T<sub>1</sub>) (10.8) recorded the lowest. Leaves being the primary site for photosynthesis are directly influenced by nitrogen availability. The addition of organic manure not only releases nitrogen gradually but also enhances the availability of other essential nutrients like phosphorus and potassium, supporting healthy leaf development.

##### 3.1.4 Leaf area

Maximum leaf area observed in T<sub>6</sub> (50% N through FYM + 50% RDF during *Kharif* and 75% RDF during *Rabi*) (11.53 dm<sup>2</sup>) and T<sub>10</sub> (50% N through GM + 50% RDF during *Kharif* and 75% RDF during *Rabi*) (11.02 dm<sup>2</sup>) and T<sub>5</sub> (100% RDF) (10.77 dm<sup>2</sup>), which were significantly higher than the control (T<sub>1</sub>) (5.45 dm<sup>2</sup>) which recorded lowest. The enhanced leaf area in integrated treatments may be due to improved cell division and enlargement driven by better nutrient status.

##### 3.1.5 Number of root nodules per plant

Root nodulation showed a marked increase with integrated nutrient applications. The highest number of nodules was recorded in T<sub>6</sub> (50% N through FYM + 50% RDF during *Kharif* and 75% RDF during *Rabi*) (38.56) which was on par with T<sub>10</sub> (50% N through GM + 50% RDF during *Kharif* and 75% RDF during *Rabi*) (36.89) and T<sub>5</sub> (100% RDF) (35.67), while control (T<sub>1</sub>) (18.78) recorded the lowest. The significant increase in nodulation under integrated treatments could be attributed to improved root growth, better microbial activity, and a conducive rhizosphere environment created by organic amendments.

#### 3.2 Effect of INM on Growth and Yield Attributes of Wheat

The application of various nutrient management treatments at MPKV, Rahuri had significant effect on growth and yield attributes of wheat, namely plant height, number of tillers per meter, leaf area per plant, panicle length, and number of spikelet per panicle. Treatments involving integration of organic and inorganic sources of nutrients demonstrated superior performance compared to control. Comparable findings have been observed by (Dhaliwal et al., 2023) and (Kondvilkar et al., 2020).

**Table 3. Effect of various levels of organic and inorganic inputs on growth and yield attributes of soybean**

Tr. No.	Plant height (cm)	No. of branches plant <sup>-1</sup>	No. of leaves plant <sup>-1</sup>	Leaf area (dm <sup>2</sup> ) plant <sup>-1</sup>	No. of root nodules plant <sup>-1</sup>
T <sub>1</sub>	64.34	2.4	10.8	5.45	18.78
T <sub>2</sub>	74.45	3.0	12.8	6.84	25.88
T <sub>3</sub>	77.43	3.4	13.2	7.56	28.51
T <sub>4</sub>	78.03	3.6	13.8	8.27	30.45
T <sub>5</sub>	83.43	4.5	14.6	10.77	35.67
T <sub>6</sub>	88.34	4.8	14.8	11.53	38.56
T <sub>7</sub>	78.56	3.8	13.8	8.45	31.78
T <sub>8</sub>	76.45	3.2	13.4	7.45	27.23
T <sub>9</sub>	77.18	3.4	13.2	7.89	28.34
T <sub>10</sub>	85.72	4.6	14.6	11.02	36.89
T <sub>11</sub>	79.88	4.2	14.2	10.23	34.23
T <sub>12</sub>	70.56	2.8	11.6	6.12	21.71
S.E. (m)±	2.70	0.13	0.47	0.29	1.04
C.D. at 5%	7.93	0.37	1.38	0.86	3.05

**Table 4. Effect of various levels of organic and inorganic inputs on growth and yield attributes of wheat**

Tr. No.	Plant height (cm)	No. of tiller m <sup>-1</sup>	Leaf area (dm <sup>2</sup> ) plant <sup>-1</sup>	length of panicle (cm)	No. of spikelet panicle <sup>-1</sup>
T <sub>1</sub>	71.59	68.8	1.12	6.95	10.14
T <sub>2</sub>	85.44	78.4	1.39	7.68	12.34
T <sub>3</sub>	91.83	83.6	1.43	8.45	14.46
T <sub>4</sub>	90.24	83.2	1.41	8.28	14.23
T <sub>5</sub>	95.65	86.8	1.58	9.32	16.39
T <sub>6</sub>	99.56	92.6	1.68	9.68	16.84
T <sub>7</sub>	89.67	81.4	1.39	8.13	13.78
T <sub>8</sub>	88.14	80.8	1.37	8.06	13.56
T <sub>9</sub>	94.93	85.4	1.51	8.90	15.67
T <sub>10</sub>	96.79	87.6	1.62	9.59	16.58
T <sub>11</sub>	93.17	85.2	1.53	9.15	14.54
T <sub>12</sub>	81.98	72.4	1.23	7.45	11.45
S.E. (m)±	1.15	1.88	0.05	0.30	0.50
C.D. at 5%	3.24	3.45	0.15	0.87	1.46

### 3.2.1 Plant height

The significantly tallest wheat plants (99.56 cm) were recorded under T<sub>6</sub> (50% N through FYM + 50% RDF during *Kharif* and 75% RDF during *Rabi*) was on par with T<sub>10</sub> (50% N through GM + 50% RDF during *Kharif* and 75% RDF during *Rabi*) with 96.79 cm and T<sub>5</sub> (100% RDF in both seasons) with 95.65 cm. The lowest plant height was recorded in T<sub>1</sub> (control) at 71.59 cm. The increased plant height in integrated treatments (T<sub>6</sub> and T<sub>10</sub>) indicates better nutrient availability, especially nitrogen from both organic and inorganic sources.

### 3.2.2 Number of tillers per meter

Maximum tillering was observed in T<sub>6</sub> (50% N through FYM + 50% RDF during *Kharif* and 75% RDF during *Rabi*) with 92.6 tillers m<sup>-1</sup> which was statistically on par with T<sub>10</sub> (50% N through GM + 50% RDF during *Kharif* and 75% RDF during *Rabi*) at 87.6 and T<sub>5</sub> (100% RDF) at 86.8. The lowest tillering was found in T<sub>1</sub> (Control) at 68.8. Treatments with organic inputs provided a continuous nutrient supply that supported higher tiller formation.

### 3.2.3 Leaf area

The significantly highest leaf area (1.68 dm<sup>2</sup>) was recorded under T<sub>6</sub> (50% N through FYM + 50% RDF during *Kharif* and 75% RDF during *Rabi*), followed by T<sub>10</sub> (50% N through GM + 50% RDF during *Kharif* and 75% RDF during *Rabi*) with 1.62 dm<sup>2</sup> and T<sub>5</sub> (100% RDF) with 1.58 dm<sup>2</sup>. In contrast, T<sub>1</sub> (Control) had the lowest leaf area (1.12 dm<sup>2</sup>). Organics like FYM and GM improve root activity and soil aeration, supporting vigorous foliage development.

### 3.2.4 Length of panicle

Panicle length was significantly influenced by treatments. The longest panicles were recorded in T<sub>6</sub> (50% N through FYM + 50% RDF during *Kharif* and 75% RDF during *Rabi*) at 9.68 cm, followed by T<sub>10</sub> (50% N through GM + 50% RDF during *Kharif* and 75% RDF during *Rabi*) at 9.59 cm, and T<sub>5</sub> (100% RDF) at 9.32 cm. The shortest was in T<sub>1</sub> (control) at 6.95 cm. Panicle length reflects the reproductive capacity of wheat. The continuous and synchronized nutrient availability under INM practices supports panicle elongation during the critical reproductive phase.

### 3.2.5 Number of spikelet per panicle

The number of spikelet per panicle was significantly highest in T<sub>6</sub> (50% N through FYM + 50% RDF during *Kharif* and 75% RDF during *Rabi*) at 16.84, followed by T<sub>10</sub> (50% N through GM + 50% RDF during *Kharif* and 75% RDF during *Rabi*) at 16.58, and T<sub>5</sub> (100% RDF) at 16.39. Lower values were observed in T<sub>1</sub> (control) at 10.14 spikelet per panicle. Organic amendments not only supply nutrients but also improve the microbial environment, which may stimulate reproductive differentiation. These findings underline the importance of INM in improving yield-attributing characters in wheat.

## 3.3 Effect of INM on Grain and Straw Yield of Soybean and Wheat

The treatment comprising 50% N through FYM combined with 50% RDF during *Kharif* and 75% RDF during *Rabi* (T<sub>6</sub>) resulted in the highest soybean grain yield (3092 kg ha<sup>-1</sup>) and straw yield (3684 kg ha<sup>-1</sup>), which was statistically at par with 50% N through GM plus 50% RDF during *Kharif* and 75% RDF during *Rabi* (T<sub>10</sub>) (2916 kg ha<sup>-1</sup>), (3512 kg ha<sup>-1</sup>) and 100% NPK application (T<sub>5</sub>) (2899 kg ha<sup>-1</sup>), (3411 kg ha<sup>-1</sup>), respectively. In contrast, the control treatment (T<sub>1</sub>) recorded the lowest yield of grain (1092 kg ha<sup>-1</sup>) and straw (1286 kg ha<sup>-1</sup>). The comparable performance of INM treatments suggests that partial substitution of chemical fertilizers with organic inputs like FYM or green manure can sustain yields while potentially improving soil health (Surve et al., 2019). The comparable results were achieved though only chemical fertilizer treatment, T<sub>5</sub> by higher nutrient availability to plants. The superior grain and straw yield of soybean in T<sub>6</sub> highlights the efficacy of FYM in enhancing nutrient availability and microbial activity. This finding aligns with the reports of (Choudhary et al., 2021) and (Dhaliwal et al., 2023).

In wheat, application of 50% N through FYM combined with 50% of the RDF during *Kharif* and 75% RDF during *Rabi* (T<sub>6</sub>) resulted in the highest wheat grain yield (3535 kg ha<sup>-1</sup>) and straw yield (4023 kg ha<sup>-1</sup>), which was statistically at par with the treatments involving 50% N through GM + 50% RDF in *Kharif* and 75% RDF in *Rabi* (T<sub>10</sub>) (3495 kg ha<sup>-1</sup>), (3889 kg ha<sup>-1</sup>), and 100% NPK application in both seasons (T<sub>5</sub>) (3334 kg ha<sup>-1</sup>), (3784 kg ha<sup>-1</sup>), respectively. The control treatment (T<sub>1</sub>) recorded the lowest wheat grain yield (1423 kg ha<sup>-1</sup>) and straw yield (1832 kg ha<sup>-1</sup>). The integration of organic

**Table 5. Effect of various levels of organic and inorganic inputs grain and straw yield of soybean and wheat**

Tr. No.	Soybean (kg ha <sup>-1</sup> )		Wheat (kg ha <sup>-1</sup> )	
	Grain yield	Straw yield	Grain yield	Straw yield
T <sub>1</sub>	1092	1286	1423	1832
T <sub>2</sub>	2282	2413	2523	2412
T <sub>3</sub>	2434	2716	3032	3154
T <sub>4</sub>	2569	2798	2846	2856
T <sub>5</sub>	2899	3411	3334	3784
T <sub>6</sub>	3092	3684	3535	4023
T <sub>7</sub>	2601	2967	2678	3724
T <sub>8</sub>	2356	2532	2579	3189
T <sub>9</sub>	2414	2469	3214	3475
T <sub>10</sub>	2916	3512	3495	3889
T <sub>11</sub>	2767	3037	3295	3578
T <sub>12</sub>	1876	2041	1923	2178
S.E. (m)±	85.78	95.52	99.09	109.5
C.D. at 5%	251.5	280.1	290.5	321.2

manures (FYM or GM) with inorganic fertilizers enhanced nutrient availability and uptake, leading to improved wheat yield. Treatments T<sub>6</sub> and T<sub>10</sub>, involving partial substitution of N with organic sources, maintained yields comparable to full NPK application, highlighting the potential for reducing chemical fertilizer use without compromising productivity. Enhanced microbial activity and better soil structure from organic amendments likely contributed to this response (Kondvilkar *et al.*, 2020) and (Patidar *et al.*, 2021). The sole application of chemical fertilizer (T<sub>5</sub>) recorded comparable result because of higher nutrient availability to plants. However, T<sub>6</sub> and T<sub>10</sub> offer added benefits of improving soil organic matter and long-term soil health. These results are consistent with those reported by (Kumar *et al.*, 2023) and (Inwati *et al.*, 2022).

#### 4. CONCLUSION

The integrated application of organic and inorganic fertilizers (50% N through FYM with 50% RDF) significantly enhanced grain and straw yield along with growth and yield attributes of soybean and wheat in Inceptisol of Western Maharashtra compared to sole application of chemical fertilizer. This INM practices not only improves the crop yield but also improves organic carbon to soil and sustain soil health in long-term.

#### DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image

generators have been used during the writing or editing of this manuscript.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

#### REFERENCES

- Bhattacharya, S. S., Kim, K.-H., Das, S., Uchimiya, M., Jeon, B. H., Kwon, E., & Szulejko, J. E. (2016). A review on the role of organic inputs in maintaining the soil carbon pool of the terrestrial ecosystem. *Journal of Environmental Management*, 167, 214-227. <https://doi.org/10.1016/j.jenvman.2015.11.009>
- Castellini, M., Diacono, M., Gattullo, C. E., & Stellacci, A. M. (2021). Sustainable agriculture and soil conservation. *Applied Sciences*, 11(9), 4146-4152. <https://doi.org/10.3390/app11094146>
- Choudhary, M., Meena, V. S., Panday, S. C., Mondal, T., Yadav, R. P., Mishra, P. K., Bisht, J. K., & Pattanayak, A. (2021). Long-term effects of organic manure and inorganic fertilization on biological soil quality indicators of soybean-wheat rotation in the Indian mid-Himalaya. *Applied Soil Ecology*, 157, 103754-103767. <https://doi.org/10.1016/j.apsoil.2020.103754>
- Dhaliwal, S. S., Sharma, V., Shukla, A. K., Gupta, R. K., Verma, V., Kaur, M., Behera,

- S. K., & Singh, P. (2023). Residual effect of organic and inorganic fertilizers on growth, yield, and nutrient uptake in wheat under a Basmati rice–wheat cropping system in North-Western India. *Agriculture*, 13(3), 556-573. <https://doi.org/10.3390/agriculture13030556>
- Inwati, D. K., Dixit, B. K., Thakur, R., Dwivedi, B. S., Sharma, A., & Singh, V. (2022). Effect of long-term fertilizer and FYM application on soil fertility of a Vertisol under soybean-wheat cropping system. *Journal of Experimental Agriculture International*, 44(10), 179-184. <https://doi.org/10.9734/jeai/2022/v44i1030423>
- Kondvilkar, N. B., Patil, S. R., Pharande, A. L., Bhakare, B. D., & Navle, A. M. (2020). Potential impact of long-term use of integrated nutrient management practices on the population of *Azotobacter* and *Azospirillum* spp. and urease activity in sorghum-wheat sequence in Vertisol. *International Journal of Current Microbiology and Applied Sciences*, 9(8), 1502-1511. <https://doi.org/10.20546/ijcmas.2020.908.169>
- Kumar, A., Verma, V. S., Sharma, D. K., & Mishra, A. K. (2023). Effect of row proportions, organic and inorganic nutrient sources on growth and yield of potato (*Solanum tuberosum*) cultivars. *Indian Journal of Agronomy*, 68(2), 205-210. <https://doi.org/10.5958/2349-1476.2023.00034.1>
- Patidar, N., Dwivedi, A. K., Dwivedi, B. S., Thakur, R. K., Bairwa, J., & Sharma, A. (2021). Impact of long-term application of inorganic fertilizers and organic manure on soil fertility and crop productivity under soybean-wheat cropping system in a Vertisol. *International Journal of Environment and Climate Change*, 11(8), 24-30. <https://doi.org/10.9734/ijecc/2021/v11i830416>
- Surve, U., Dhonde, A., Kumbhar, J., & Bhosale, P. (2019). Effect of integrated nutrient management on productivity, nutrient uptake, soil properties, and economics of soybean-wheat cropping system in Western Maharashtra. *International Journal of Chemical Studies*, 7(2), 497-500.
- Tahat, M., Alananbeh, K. M., Othman, Y. A., & Leskovar, D. I. (2020). Soil health and sustainable agriculture. *Sustainability*, 12(12), 4859-4885. <https://doi.org/10.3390/su12124859>

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