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EFFECT OF ORGANIC LEAF MULCHING AND FARMYARD MANURE ON SOIL NUTRIENT DYNAMICS AND SOIL FERTILITY IMPROVEMENT UNDER FIELD CONDITIONS

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ABSTRACT

A field experiment was conducted during 2023-24 and 2024-25 to evaluate the effect of different organic leaf mulcheson soil nutrient dynamicsunder field conditions. Twelve treatments comprising various organic residues *viz*., leaves of *Madhuca indica*, *Dalbergia sissoo*, *Azadirachta indica*, *Lantana camara*, *Duranta erecta*, *Cynodon dactylon*, *Cyperus rotundus*, sugarcane leaves, pulse straw mulch, adequate control, no mulching, and FYM application were evaluated in a randomized experimental design.The results revealed that the significant improvement in soil nutrient availability due to organic mulching and FYM application compared with control treatments. Available nitrogen showed higher values under pulse straw mulch and FYM treatments across both cropping years. Available phosphorus increased progressively in the second year, with FYM impact recording the maximum values (13.18 and 16.55 kg ha^{-1} during 2023-24 and 2024-25, respectively), followed by pulse straw mulching. Similarly, available potassium content was significantly influencedwith *Cynodon dactylon* mulching, recording the highest potassium during 2023-24 (298.15 kg ha^{-1}), while FYM application resulted in maximum potassium availability (311.98 kg ha^{-1}) during 2024-25 due to cumulative nutrient buildup.Overall, nutrient availability was higher during 2024-25 compared to 2023-24, indicating residual and cumulative effects of organic residues on soil fertility. Organic mulching improved nutrient recycling, moisture conservation, and microbial activity, thereby enhancing soil health and maintaining long-term agricultural productivity.

***Key words*:** Organic mulching, FYM, Soil fertility, Nutrient cycling, Sustainable agriculture.

Introduction

Decline soil fertility levels and imbalance use of mineral nutrient become major limitationsfor sustainable agricultural production mainly in intensive cropping systems (Singh *et al.*, 2024). Continuous use of chemical fertilizers and addition of insufficientamount of organic matter have resulted in declining of physical, chemical, and biological soil properties (Chan *et al.*, 2018). Maintaining soil fertility and nutrient availability is essential for sustainable crop productivity and environmental health. However, use of organic amendments such as farmyard manure and organic mulching materials has increased significant and eco-friendly sustainable soil management strategy (Chen *et al.*, 2018; Kumar *et al.*, 2018). Organic mulching involved the covering soil surface with plant residues or other organic materials to conserve soil moisture, regulate soil temperature, suppress weed density and improve soil fertility overresidues decomposition. The decomposition of organic residues enhances microbial activity and improves nutrient cycling which ultimately increases the availability of essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K) for the plants (Li *et al.*, 2018; Sun *et al.*, 2021). In addition, mulching protects the soil surface from erosion and reduces nutrient losses through runoff and volatilization losses of nutrients.

Table 1: Initial soil properties of the experimental sites.

S.No.	Soil Parameters	2023-24	Methods used
1	Soil Reaction (pH)	7.20	Glass Electrode pH meter (Muhur *et al*., 1965)
2	Electrical Conductivity (dS/ m) at 25°C	0.33	Solubridge method (Richard, 1954)
3	Organic Carbon (%)	0.42	Walkley and Black's Rapid Titration method (Piper, 1950).
4	Available Nitrogen (kg/ha)	170.50	Alkaline permanganate method (Subbiah and Asija, 1956)
5	Available Phosphorus (kg/ha)	12.20	Olsen's method (Olsen *et al*., 1954)
6	Available potassium (kg/ha)	250.00	Flame Photometer (Muhur *et al*.,1965)

Farmyard manure (FYM) is one of the most commonly used organic amendments in sustainable farming systems. It is a mixture of cattle dung, urine, bedding materialsand leftover feeding materialscontribute as rich source of organic matter and plant nutrients. The application of FYM improves soil structure, enhances water holding capacity and promotes beneficial microbial populations in soil. Moreover, FYM plays significant role in improving soil nutrient status by increasing the availability of macro and micronutrients (Jain *et al*., 2017; Zhou *et al*., 2022). The combined use of organic mulching and farmyard manure can synergisticallyeffect on soil nutrient dynamics and soil fertility. Whereas, FYM supplies nutrients and organic matter in the soil and organic mulches slowly release nutrients through decomposition can also improve soil microclimate conditions(Kumar *et al*., 2018; Li *et al*., 2018; Larkin, 2020; Sun *et al*., 2021). This integrated approach not only improves nutrient availability but also enhances soil biological activity and organic carbon content andimportant for long-term improvements of soil health and sustainability (Larkin, 2020; Agrawal *et al*., 2022).

Soil nutrient dynamics refer to the transformation, availability and movement of nutrients within soil system. Organic amendments influence these processes by stimulating microbial decomposition, mineralization, and immobilization of nutrients. Improved nutrient dynamics ultimately contribute to higher nutrient uptake by crops and better soil fertility status. Several studies have reported that the incorporation of organic residues and FYM significantly increases soil organic carbon and available N, P, and K compared with conventional practices (Chen *et al*., 2018; Sun *et al*., 2021). Considering the collective importance for sustainable soil management use of organic mulches along with farmyard manure can play a vital role in restoring soil fertility and maintaining nutrient availability under field conditions. However, the scope of combined effects on soil nutrient dynamics and fertility improvement may differ depending on the type of mulching material, decomposition rate and soil environmental conditions. Therefore, the present study was undertaken to evaluate the effect of organic leaf mulching and farmyard manure on soil fertility improvement under field conditions, aiming to identify efficient organic resource management strategies for sustainable agricultural production.

Materials and Method

The present investigation was carried out at Department of Agronomy, Institute of Agricultural Sciences, Bundelkhand University, Jhansi (U.P.) during two concentrical *rabi* season 2023-24 and 2024-25. The field experiments were carried out with twelve treatments and five replications laid out in Randomized Block Design (RBD). The experimental site is situated in the semi-arid condition, at 25°27'31" N latitude and 78°34'47" E longitude and 258 m above mean sea level (MSL). The soil of experimental field is consequential sandy loam in texture (Red in Color), medium in organic carbon (0.42%), low in available nitrogen (170.50 kg ha^{-1}) and medium in available phosphorous (12.20 kg ha^{-1}) and medium in available potassium (250.00 kg ha^{-1}) with neutral in soil reaction (pH 7.20) (Table 1). The average rainfall is about 750 mm, most of which is received from South-West monsoon during June to September. The experiment comprised of 12 treatments *viz*., T1- Leaves of *Madhuca indica*, T2- Leaves of *Dalbergia sisso*, T3- Leaves of *Azadirchta indica*, T4- Leaves of *Lantana camera*, T5- Leaves of *Duranta erecta* , T6- Leaves of *Cynodon dactylon*, T7- Leaves of *Cyperus rotundus*, T8- Leaves of *Saccharum officinarum*, T9-Leaves of pulse straw, T10- Adequate control, T11- No Mulching and T12- FYM Impact. The Chickpea 'JG-16' was sown in month of October during both cropping sessions. The recommended dose of natural farming fertilizer was applied in all the treatment except adequate control and T12, and broadcasted at the time of sowing.

The representative soil samples were collected from experimental plots at 0–15 cm depth using a soil auger after the harvesting of crop within the treatments in month of April 2024 and 2025. The composite soil samples were air dried in a shed house and grained with wooden mortal and petal and passed through a 2 mm sieve for laboratory analysis. The soil samples were analyzed for standard laboratory protocols. The organic carbon content of the soil sample was determined following the wet digestion

Table 2: Effect of organic mulching on available nitrogen (Av. N, kg ha^{-1}) at the end of cropping session.

Treatments Notation	Treatments details	Av. N (kg ha^{-1})(2023-24)	Av. N (kg ha^{-1})(2024-25)
T1	Leaves of *Madhuca indica*	168.71	178.51
T2	Leaves of *Dalbergia sisso*	176.83	186.63
T3	Leaves of *Azadirchta indica*	176.67	186.47
T4	Leaves of *Lantana camera*	160.96	178.76
T5	Leaves of *Duranta erecta*	168.49	178.29
T6	Leaves of *Cynodon dactylon*	170.03	179.83
T7	Leaves of *Cyperus rotundus*	171.16	180.96
T8	Leaves of Sugar cane	172.65	182.45
T9	Leaves of pulse straw	162.61	188.41
T10	Adequate control	166.50	166.30
T11	No Mulching	167.89	161.69
T12	FYM Impact	166.50	192.30
	CD ($p<0.05$)	**NS**	**17.32**
	SEm (±)	**4.01**	**6.06**

method (Walkley and Black, 1934). The determination of available nitrogen was analyzed by Alkaline Permanganate Method. The easily oxidizable organic nitrogen in soil is oxidized by alkaline potassium permanganate ($KMnO_4$), releasing ammonia (NH_3). The liberated ammonia is absorbed in boric acid and titrated with standard sulfuric acid (Subbiah and Asija, 1956). Soil phosphorus is extracted using 0.5 M sodium bicarbonate ($NaHCO_3$) at pH 8.5. Extracted P reacts with ammonium molybdate forming phosphomolybdate complex, which develops blue color after reduction and is measured spectrophotometrically (Olsen *et al*., 1954). The Determination of Available Potassium was analyzed by Neutral Normal Ammonium Acetate Extraction. The Exchangeable potassium is extracted with neutral 1N ammonium acetate solution. Potassium concentration is measured using a flame photometer (Hanway and Heidel, 1952).

The mean data were analyzed using two-way analysis of variance (ANOVA) technique following the randomized block design (RBD). The data analysis was done by the using with OP stat statistical software. The significance of the treatment effect was determined using F-test, and to compare the significance difference between two treatments, critical difference (CD) was estimated at $P < 0.05$.

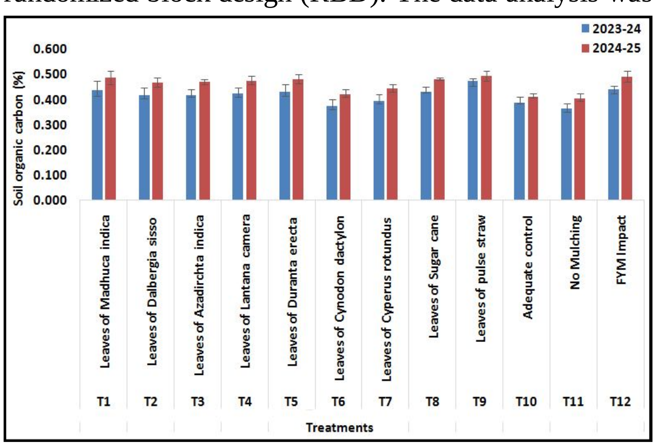

Fig. 1: Effect of different mulching materials on soil organic carbon concentration in sandy soils.

Results and Discussion

Soil organic carbon concentration

The mean data presented in the (Fig. 1) indicate the effect of different organic leaf mulches on organic carbon concentration during 2023–24 and 2024–25 cropping seasons. The mean values clearly show variation among treatments, reflecting the influence of organic mulching on soil organic carbon significantly higher during the both years of the crop harvest than the other treatments. During the both years treatment T9 (Leaves of pulse straw) recorded the highest mean value (0.48% and 0.49%), followed by T12 (FYM impact) (0.44%) and T1 (Leaves of *Madhuca indica*) (0.44%). Sensible concert was observed under T8 (Sugarcane leaves, 0.43%) and T5 (*Duranta erecta* leaves, 0.43%). The lowest value was recorded in T11, followed by T6 and T10 (Adequate control, 0.39%). Mean data clearly indicates that mulching treatments significantly higher than the non-mulched adequate control treatments.

The superior performance of organic mulch treatments may be attributed to improved soil moisture conservation, moderated soil temperature, enhanced microbial activity, and gradual nutrient release during decomposition. Organic residues such as pulse straw decompose relatively faster due to favourable C:N ratio, which enhances nutrient mineralization and improves plant growth parameters. Organic mulching improves soil porosity and water retention, thereby supporting root development and nutrient uptake. Studies have reported

Table 3: Effect of organic mulching on available phosphorous (Av. P, kg ha^{-1}) at the end of cropping session.

Treatments Notation	Treatments details	Av. P (kg ha^{-1})(2023-24)	Av. P (kg ha^{-1})(2024-25)
T1	Leaves of *Madhuca indica*	12.18	14.35
T2	Leaves of *Dalbergia sisso*	12.012	14.58
T3	Leaves of *Azadirchta indica*	11.54	14.11
T4	Leaves of *Lantana camera*	11.71	12.68
T5	Leaves of *Duranta erecta*	12.13	14.30
T6	Leaves of *Cynodon dactylon*	11.25	13.42
T7	Leaves of *Cyperus rotundus*	12.39	12.96
T8	Leaves of Sugar cane	10.61	13.18
T9	Leaves of pulse straw	12.38	15.35
T10	Adequate control	11.26	11.83
T11	No Mulching	12.13	14.30
T12	FYM Impact	13.18	16.55
	CD ($p<0.05$)	**NS**	**2.01**
	SEm (±)	**0.72**	**0.70**

that organic mulches increase soil organic carbon and microbial biomass through gradual decomposition processes, ultimately improving plant performance (Sun *et al.*, 2021).

The better results under FYM application (T12) may be due to its balanced nutrient supply and stimulation of microbial activity. Farmyard manure improves soil aggregation, nutrient availability, and biological processes, which enhances crop response over time. The consistently poor performance under no-mulching treatment confirms that exposed soil suffers from higher evaporation losses and reduced nutrient-use efficiency. Mulching reduces soil evaporation and enhances water and nitrogen use efficiency, leading to improved crop performance compared with bare soil conditions (Qin *et al.*, 2015). Variation among leaf mulches can be explained by differences in lignin content, decomposition rate, and nutrient composition. Residues with moderate decomposition rates provide sustained nutrient release and long-term soil improvement. Organic mulching has also been shown to improve soil structure and aggregate stability, which supports sustained productivity (Zhou *et al.*, 2022). Furthermore, mulch cover suppresses weed growth and conserves soil moisture, indirectly improving crop growth and yield attributes as reported in several agronomic studies (Agrawal *et al.*, 2022). Long-term application of organic residues enhances soil organic matter and improves physical and chemical soil properties compared to unmulched soils (Joedan *et al.*, 2010).

Available Nitrogen (Av. N, kg ha^{-1})

The mean data presented in Table 2 reveal that the influence of different organic leaf mulches on available nitrogen (Av. N) during 2023–24 and 2024–25 cropping seasons. Considerable variation among treatments was observed. During the first experimental year, treatment differences were clearly evident. The highest mean value was recorded under T3 (Leaves of *Azadirachta indica*) (176.83 kg ha^{-1}), which was statistically at par with T4 (*Lantana camara* leaves, 176.67 kg ha^{-1}). Other superior treatments included T9 (Pulse straw mulch, 172.65 kg ha^{-1}) followed by T8 (Sugarcane leaves, 171.16 kg ha^{-1}). Medium Av. N were obtained with T7 (*Cyperus rotundus* leaves, 170.03 kg ha^{-1}) followed by T2 (*Dalbergia sissoo* leaves, 168.71 kg ha^{-1}). Lower performance was observed under T5 (*Duranta erecta* leaves, 160.96 kg ha^{-1}) followed by T10 (Adequate control, 162.61 kg ha^{-1}). The minimum mean value was recorded under T11 (No mulching, 166.50 kg ha^{-1}) compared with most mulched treatments, highlighting the beneficial effect of mulch application. Overall, the mean value of the Av. N data non-significant during the first cropping year.

The maximum mean value was obtained in T10 (Adequate control, 188.41 96 kg ha^{-1}), followed closely by T3 (*Azadirachta indica* leaves, 186.63 96 kg ha^{-1}) and T4 (*Lantana camara* leaves, 186.47 96 kg ha^{-1}). Treatments T9 (Pulse straw, 182.45 96 kg ha^{-1}) and T8 (Sugarcane leaves, 180.96 96 kg ha^{-1}) also performed well. The lowest values were observed under T12 (FYM impact, 161.69 96 kg ha^{-1}) and T11 (No mulching, 166.30 96 kg ha^{-1}), indicating comparatively lower effectiveness during second year. The improved performance under organic mulch treatments may be attributed to enhanced soil moisture retention, moderated temperature fluctuations, improved microbial activity, and gradual nutrient mineralization. Organic residues act as a protective soil cover, reducing evaporation losses and improving nutrient-use efficiency.

Organic leaves mulches from *Azadirachta indica*

Table 4: Effect of organic mulching on available potassium (Av. K, kg ha^{-1}) at the end of cropping session.

Treatments Notation	Treatments details	Av. K (kg ha^{-1})(2023-24)	Av. K (kg ha^{-1})(2024-25)
T1	Leaves of *Madhuca indica*	257.12	273.29
T2	Leaves of *Dalbergia sisso*	249.21	266.40
T3	Leaves of *Azadirchta indica*	242.88	260.06
T4	Leaves of *Lantana camera*	241.37	258.56
T5	Leaves of *Duranta erecta*	241.46	258.64
T6	Leaves of *Cynodon dactylon*	298.15	305.34
T7	Leaves of *Cyperus rotundus*	268.54	285.72
T8	Leaves of Sugar cane	259.63	276.82
T9	Leaves of pulse straw	268.52	285.70
T10	Adequate control	273.38	248.57
T11	No Mulching	268.45	285.63
T12	FYM Impact	271.47	311.98
	CD (*p<0.05*)	**28.20**	**31.44**
	SEm (±)	**9.86**	**10.99**

and *Lantana camara* showed greater results, due to balanced decomposition rates and release of essential nutrients that support sustained crop growth. Organic residues improve soil aggregation and increase biological activity, which enhances nutrient availability and plant performance. Pulse straw and sugarcane leaf mulches also performed well because crop residues generally possess favourable carbon-to-nitrogen ratios, enabling steady nutrient release during decomposition. Similar findings were reported by Kader *et al.*, (2019), who observed improved crop growth and soil hydrothermal regimes under organic mulching systems.

The comparatively poor performance under no-mulching treatment confirms that adequate control conditions lead to higher moisture loss, nutrient depletion, and reduced biological activity. Mulching has been widely reported to increase water-use efficiency and improve crop productivity compared with unmulched soil (Singh *et al.*, 2018). The variation between years suggests cumulative effects of organic matter addition. Continuous mulch application improves soil organic carbon and microbial biomass, which positively influences soil fertility over time. Long-term organic amendments enhance soil structure, infiltration, and nutrient cycling, resulting in improved crop response (Lal, 2020).

Available phosphorous (Av. P, kg ha^{-1})

The mean data presented in the Table 3 show that the effect of different organic leaf mulches, FYM application on available phosphorus content of soil during the cropping seasons 2023–24 and 2024–25. The results indicate noticeable variation among treatments. Results revelled that the available phosphorus non-significant during before first year crop harvest. The highest value was recorded under T12 (FYM impact) (13.18 kg ha^{-1}), followed by T7 (*Cyperus rotundus* leaves, 12.39 kg ha^{-1}) and T9 (Pulse straw mulch, 12.38 kg ha^{-1}). The lowest available phosphorus content was observed under T8 (Sugarcane leaves, 10.61kg ha^{-1}), followed by T10 (Adequate control, 11.26 kg ha^{-1}) and T6 (*Cynodon dactylon* leaves, 11.25 kg ha^{-1}).

Results of mean data revelled that the phosphorus availability significant higher during before 2024-25 cropping session. The maximum phosphorus availability was again recorded under T12 (FYM impact, 16.55 kg ha^{-1}), followed by T9 (Pulse straw mulch, 15.35 kg ha^{-1}) and T2 (*Dalbergia sissoo* leaves, 14.58 kg ha^{-1}). The minimum value occurred under T10 (Adequate control, 11.83 kg ha^{-1}), indicating lower phosphorus availability in the absence of organic residue addition.

The increase in available phosphorus under organic mulching and FYM treatments may be attributed to enhanced mineralization of organic matter, microbial activity, and organic acid production during decomposition of organic mulches. During the decomposition of organic residues release organic acids that reduce phosphorus fixation and convert unavailable phosphorus into plant-available forms. Farmyard manure recorded the highest phosphorus availability because it supplies phosphorus directly and stimulates microbial populations responsible for phosphorus solubilization microorganisms. Similar findings were reported by Lal (2015) and Goyal *et al.*, (2019), who observed increased available phosphorus following continuous organic manure application.

Pulse straw mulching realized well due to its relatively balanced C:N ratio, which favors faster decomposition and nutrient release. Crop residues enhance phosphatase enzyme activity in soil, thus, improving phosphorus mineralization. According to Kader *et al.*, (2017), organic mulching significantly enhances nutrient cycling and improves soil fertility through microbial activity. Lower phosphorus availability under control treatments may be due to absence of additional organic inputs, resulting in higher phosphorus fixation and reduced microbial activity. Bare or nutrient-limited soils often show reduced phosphorus availability because of strong adsorption by soil minerals, especially under tropical and semi-arid conditions. Continuous addition of organic residues enhances phosphorus cycling and progressively buildup soil fertility and supporting sustainable nutrient management.

Available Potassium (Av. K, kg ha^{-1})

The mean data presented in the Table 4 illustrate that the effect of different organic leaf mulches, on soil available potassium during both cropping sessions. During the both of cropping session the result significantly higher that the control. The highest potassium content was recorded under T6 (Leaves of *Cynodon dactylon*) (298.15 kg ha^{-1}), followed by T10 (Adequate control, 273.38 kg ha^{-1}) and T12 (FYM impact, 271.47 kg ha^{-1}). Treatments T7 (*Cyperus rotundus* leaves, 268.54 kg ha^{-1}) and T9 (Pulse straw mulch, 268.52 kg ha^{-1}) also maintained higher potassium levels. The lowest potassium availability occurred under T4 (*Lantana camara* leaves, 241.37 kg ha^{-1}) and T5 (*Duranta erecta* leaves, 241.46 kg ha^{-1}).

The available potassium increased under different treatments, showing cumulative benefits of organic matter incorporation in both years. The maximum potassium availability was recorded under T12 (FYM impact, 311.98 kg ha^{-1}), followed by T6 (*Cynodon dactylon* leaves, 305.34 kg ha^{-1}). Treatments T7 (285.72 kg ha^{-1}), T9 (285.70 kg ha^{-1}) and T11 (No mulching, 285.63 kg ha^{-1}) also recorded comparatively higher values. The minimum value was observed under T10 (Adequate control, 248.57 kg ha^{-1}).

The increase in available potassium under organic mulch can be attributed to the release of potassium during decomposition of plant residues. Unlike nitrogen and phosphorus, potassium exists largely in soluble and exchangeable forms in plant tissues and is rapidly released into soil upon residue breakdown. The greater performance of *Cynodon dactylon* leaf mulch (T6) may be due to its relatively higher potassium content and faster mineralization, contributing directly to soil exchangeable potassium. Organic mulches enhance soil moisture retention and microbial activity, which promotes mineral weathering and potassium release from soil minerals. FYM application recorded the highest potassium availability during the second year, indicating cumulative improvement in soil nutrient reserves. Farmyard manure increases cation exchange capacity and reduces potassium leaching losses, thereby improving potassium retention in soil. Similar findings were reported by Mandal *et al*., (2018) and Lal (2020), who observed enhanced exchangeable potassium following continuous organic amendments. Lower potassium values under certain leaf mulches may be associated with slower decomposition rates or higher lignin content, which delays nutrient release. The comparatively reduced potassium under adequate control during 2024-25 suggests nutrient depletion in absence of continuous organic additions.

Conclusion

The results of the study clearly demonstrated that application of organic mulches and farmyard manure significantly influenced soil nutrient availability and overall soil fertility status during both experimental years. The results indicated that incorporation of organic residues enhanced the soil organic carbon sequestration as well as availability of major nutrients (N, P, and K) compared with control and non-mulched treatments. Among the different treatments, pulse straw mulch and FYM application consistently improved soil nutrient status, reflecting enhanced decomposition, nutrient mineralization, and improved biological activity in soil. Similarly, higher nitrogen availability under organic mulching treatments improved microbial diversity resulting consistentally nutrient supplying. Organic leaf mulches contributed to improved soil conditions by conserving moisture, moderating soil temperature, and promoting microbial activity, which collectively enhanced nutrient cycling. However, no-mulching and control treatments recorded comparatively lower nutrient availability, highlighting the importance of soil cover and organic matter addition for maintaining soil productivity.

Overall, the findings suggested that integration of organic leaf mulching, particularly pulse straw mulch, along with FYM application is an effective and sustainable strategy for improving soil nutrient dynamics, enhancing soil fertility, and supporting long-term agricultural sustainability under field conditions. Adoption of such practices can contribute to resource conservation, improved soil quality, and resilient crop production systems.

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