

# Physico-chemical characteristics of soil as affected by organic amendments in coloured capsicum grown under greenhouse conditions

## Abstract

Organic manures and bio-fertilizers are one of the alternative renewable sources of nutrient supply. Bio-fertilizers combined with organic manure influences the plant growth by enhancing root biomass; total root surface facilitates higher absorption of nutrients and increase in yield by reducing consumption of natural sources of energy. In this experiment, various types of organic sources of nutrients (FYM, Poultry manure, Vermicompost and Sheep manure) and biofertilizers (*Azotobacter*, PSB and KSB) were evaluated in coloured capsicum under greenhouse conditions and their impact was studied on various physico-chemical properties of soil. Observations were recorded on various physical parameters like pH, soil EC, soil OC, soil bulk density, chemical parameters like available N, P, K and uptake of nutrient N, P and K. Data on various soil parameters revealed that T<sub>5</sub> (75% vermicompost+ Azotobacter+ PSB+ KSB) significantly enhanced available soil nutrients and resulted in maximizing the nutrient status of the soil after the crop harvest. Highest available N (220.13kg/ ha), P (30.24kg/ ha), K (222.16kg/ ha) was recorded in treatment T<sub>5</sub> and was found maximum as compared to all other treatments under study. However, the uptake of nutrients was observed maximum in treatment T<sub>9</sub> (RFD). Treatment T<sub>5</sub> (75% vermicompost + azotobacter +PSB +KSB) also contributed in improving the physical parameters of soil like electrical conductivity (0.114 dsm<sup>-1</sup>) and soil organic carbon content (1.37%) than initial status of soil, recording EC of 0.102 dsm<sup>-1</sup> and organic carbon content of 1.19%. Additionally, the organic manures also brought the pH of soil to a desired level and pH was declined from 7.02(initial status) to 6.81 by treatment T<sub>5</sub> (75% vermicompost + azotobacter +PSB +KSB). But treatment T<sub>2</sub> (100% Poultry manure) improved the bulk density of soil and was reduced to 1.22 g/cm<sup>3</sup> as compared to initial soil status recording bulk density of 1.38 g/cm<sup>3</sup>.

## Introduction

Capsicum (*Capsicum annum* L.) also known as Bell pepper, sweet pepper, green pepper and Shimla mirch is one of the popular Solanaceous vegetable crop grown throughout India in open as well as protected environments. Capsicum attained a status of high value low volume crop in India in recent years and occupies a place of pride among vegetables in Indian cuisine. Also, coloured capsicum ensures a lucrative revenue return owing to its high-value vegetable. This crop is having good storability and can be stored in the cold storage facility even up to one month. Capsicum can be grown throughout the year under the protected structure and if grown organically, can fetch a high profit. Basically, these are the perfect items for selling from shopping malls, supermarkets, and online marketplaces.

Bell peppers come with enormous health benefits like it contains plenty of vitamin C. However, the highest amount of Vitamin C is in red variety. Additionally, Red bell peppers help in activating thermogenesis and increase the metabolic rate. Hence, it supports weight

loss. Coloured capsicums also contain several phytochemicals and carotenoids, particularly beta-carotene. These are also a good source of vitamin E, vitamin B6 as well (Nkansah et al., 2017).

Cultivation of capsicum under protected structures is gaining momentum due to increased demand for the produce throughout the year. Cultivation of capsicum in the cost effective naturally ventilated polyhouses is proving to be a very remunerative venture. A naturally ventilated greenhouse works effectively in temperature range of 15-35 °C. The cultivation of capsicum in net house can play a better role in improving quality, advancing maturity as well as increasing fruiting span and productivity. Keyhaninejad et al., 2012 reported that greenhouse and shade house reduced light intensity that resulted in a two- to three-fold increase in carotenoid content in pepper fruit (*Capsicum annuum*) as compared to open-field conditions. Moreover, production of capsicum under controlled environment has high production per unit area of land and extended harvest period. Higher yields are reported when capsicum is grown under protected structures. Sweet pepper grown in greenhouse can produce yield up to 100 t/ha (Singh et al., 2011).

Among the various factors responsible for low production of coloured capsicum, nutrition is of prime importance. Many investigators reported that the supply of balanced nutrition had a major effect on plant growth (Feng et al., 2010; Shahin et al., 2010), total yield (Zhang et al., 2010) and quality of sweet pepper (Akande et al., 2007). But, application of chemical fertilizers alone supplies only major nutrient elements to the crop. The chemical fertilizers are known to degrade soil and water resources. However, the modern day's agriculture is focused not only for production but also accounts for the sustainability of all the resources including soil for the generations to come. So, the alternative farming system which is sustainable and self-sufficient is the organic farming. Organic farming is an agricultural production system, involving locally and naturally available organic materials or agro inputs, without endangering our precious natural resources. Organic manures and bio-fertilizers are one of the alternative renewable sources of nutrient supply. Organic manure not only supply macro, micro, and secondary nutrient, but also improve physical, chemical and biological properties of soil. Organic manures are slow releasing fertilizers and loss of nutrients is less than inorganic fertilizers resulting in reduction of soil, water and air pollution. It can supply practically all the elements of soil fertility that the crops require when applied in right proportions. Additionally, organic manures contain enzymes like amylase, lipase, cellulase and chitinase which continues to break down organic matter in the soil (to release the nutrients and make it available to the plant roots). These also contain several plant growth promoters, enzymes rich in plant nutrients, beneficial bacteria and mycorrhizae. In contrast, Bio-fertilizers are the preparations containing living or latent cells of efficient strains of microorganisms capable of fixing atmospheric nitrogen, solubilizing phosphorous and potassium, mobilizing nutrients and absorption of water, decomposing cellulolytic and alginolytic water materials. These are low cost, eco-friendly input and not only improve the crop growth and yield but also improve fertilizer use efficiency. These also produces growth promoting substances (IAA and GA) which greatly influences the seed germination, root growth and proliferation. According to Fawzyet al. (2012) application of bio-fertilizer increased ascorbic acid in sweet pepper fruits. Also, Bashan and Leavanany (1989) obtained

higher fruit yield of bell pepper with *Azospirillum* inoculation of seedlings under greenhouse condition.

We hypothesized that the physico-chemical characteristics of soil were significantly affected by the use of various organic manures and biofertilizers in the study due to the positive benefits it offers towards successive crop growth and development. Hence, the focus of this research was to see how different organic amendments affected the overall soil health in coloured capsicum grown under protected conditions in temperate conditions.

## Methodology

The present investigation was carried out at Experimental Farm, Division of vegetable science, SKUAST-Kashmir Shalimar campus, during kharif 2020, which is 15km away from Srinagar city that lies between 34.10 North latitude and 74.89o East longitude at an altitude of 1587 meters above mean sea level. The F1 Hybrid used in this experiment was Ayesha. Three types of bio-fertilizers viz., Azotobacter, PSB, KSB and four types of organic manures viz., vermicompost, sheep manure, farmyard manure and poultry manure were used as nutrient sources in different combinations. The experiment comprised of 9 treatments viz, T1= 100% Vermicompost, T2= 100% poultry manure, T3= 100% FYM, 100% sheep manure, T4=75% vermicompost+Azotobacter+PSB+KSB, T5=75%Poultrymanure+Azotobacter+PSB+KSB, T6= 75% FYM + Azotobacter + PSB + KSB, T7=75% FYM + Azotobacter + PSB + KSB, T8=75% Sheep manure+Azotobacter+PSB+ KSB, T9= Control (Recommended fertilizer dose). The biofertilizers were applied @2.5 litre/ha. The biofertilizers were applied as seedling dip method for 30 minutes before transplanting. The organic manures were applied on N equivalent basis as per the recommended dose of fertilizers. All the organic manures were incorporated in the experimental field 10-15 days before transplanting. The experiment had 3 replications which were laid out in Randomized Complete Block Design(RCBD).

Representative soil samples of the experimental site before the start of experiment as well as after the harvest of crop from each treatment were taken from a depth of 0-15 cm and analysed for physico-chemical properties viz., Electrical Conductivity, pH, Organic Carbon, Bulk Density and Available Nitrogen, Phosphorus, Potassium (kg/ha).

The initial status of experimental site with respect to above characteristics is given as:

**Table-1: Physico-chemical properties of soil of experimental site**

Particulars	Initial status
Soil pH	7.02
Electrical Conductivity (ds/m)	0.102
Organic Carbon (%)	1.19
Bulk Density (g/cm <sup>3</sup> )	1.38
Available N (kg/ha)	210.50
Available P (kg/ha)	22.75

Available K (kg/ha)	205.20
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The Organic manures were also analysed for the nutrient status given as under:

**Table-2: Chemical composition of organic manures used in the experiment**

Organic manure	Per cent N	Per cent P	Per cent K
Vermicompost	2.0	1.2	0.6
Farmyard manure	0.6	0.4	0.5
Poultry manure	1.8	1.6	0.8
Sheep manure	0.7	0.3	0.9

Transplanting was done in well prepared field and all standard practices were followed for raising the crop. The data pertaining to growth, yield, quality and soil health was recorded and was subjected to statistical analysis using standard procedures.

## Experimental Results

### Effect of different organic amendments on physico-chemical properties of soil

Among the different organic amendments, treatment T<sub>5</sub> (75% VC+ Azotobacter+ PSB+ KSB) recorded a soil pH of 6.81, EC (0.114ds/m) and Organic carbon (1.37%), depicting a significant difference as compared to the initial status of soil with pH (7.02), EC (0.102 ds/m) and organic carbon (1.19%) as presented in Table-3. The data pertaining to bulk density presented in Table-3 reveal a significant variation in bulk density of soil after harvesting of crop. Among all the treatments, sole organic treatments resulted in more improvement in bulk density as compared to integrated organic treatments. Among sole treatments, treatment T<sub>2</sub> (100% poultry manure) recorded a bulk density of 1.22 g/cm<sup>3</sup> followed by T<sub>4</sub> (100% SM) having bulk density of 1.23 g/cm<sup>3</sup>. Whereas, among integrated organic amendments T<sub>6</sub> (75% poultry manure @ 6.24 t ha<sup>-1</sup> + Azotobacter+PSB+ KSB) recorded a bulk density of 1.26g/cm<sup>3</sup> and was followed by T<sub>8</sub> (75% SM+ Azotobacter+ PSB+ KSB) with density of 1.27 g/cm<sup>3</sup>. Moreover, T<sub>9</sub> (RFD) which did not receive any organic manures, recorded a least improvement in physico-chemical properties of soil.

**Table-3. Effect of different organic amendments on physico-chemical properties of soil**

S.No	Treatment details	pH	EC (dS/m)	Bulk density (g/cm <sup>3</sup> )	Organic carbon (%)
T <sub>1</sub>	100%vermicompost @ 7.5t ha <sup>-1</sup>	6.88±0.01 <sup>cd</sup>	0.110±0.00 <sup>bcde</sup>	1.25±0.01 <sup>abcd</sup>	1.29±0.01 <sup>de</sup>
T <sub>2</sub>	100% poultry manure @ 8.3t ha <sup>-1</sup>	6.95±0.03 <sup>fg</sup>	0.106±0.00 <sup>ab</sup>	<b>1.22±0.01<sup>a</sup></b>	1.23±0.01 <sup>ab</sup>
T <sub>3</sub>	100% farmyard manure @ 24.9t ha <sup>-1</sup>	6.93±0.03 <sup>ef</sup>	0.108±0.00 <sup>abcd</sup>	1.24±0.02 <sup>abc</sup>	1.26±0.01 <sup>cd</sup>

T <sub>4</sub>	<b>100% sheep manure @ 21.43 t ha<sup>-1</sup></b>	6.90±10.02 <sup>de</sup>	0.107±0.00 <sup>abc</sup>	1.23±0.02 <sup>ab</sup>	1.25±0.02 <sup>bc</sup>
T <sub>5</sub>	<b>75% vermicompost @ 5.62 t ha<sup>-1</sup> + Azotobacter+ PSB+KSB</b>	<b>6.81±0.01<sup>a</sup></b>	<b>0.114±0.00<sup>f</sup></b>	1.30±0.01 <sup>ef</sup>	<b>1.37±0.01<sup>h</sup></b>
T <sub>6</sub>	<b>75% poultry manure @ 6.24 t ha<sup>-1</sup> + Azotobacter+PSB+ KSB</b>	6.85±0.01 <sup>bc</sup>	0.111±0.00 <sup>cdef</sup>	1.26±0.03 <sup>bcde</sup>	1.31±0.01 <sup>ef</sup>
T <sub>7</sub>	<b>75% farmyard manure @ 18.7 t ha<sup>-1</sup> + Azotobacter+ PSB+KSB</b>	6.87±0.02 <sup>bcd</sup>	0.113±0.00 <sup>ef</sup>	1.28±0.02 <sup>de</sup>	1.35±0.02 <sup>gh</sup>
T <sub>8</sub>	<b>75% sheep manure @ 16.07 t ha<sup>-1</sup> + Azotobacter+PSB+ KSB</b>	6.83±0.02 <sup>ab</sup>	0.112±0.00 <sup>def</sup>	1.27±0.02 <sup>cde</sup>	1.33±0.01 <sup>fg</sup>
T <sub>9</sub>	<b>RFD@ (150 kg N, 120 kg P, 90 kg K/ ha) (Control)</b>	6.98±0.05 <sup>g</sup>	0.105±0.00 <sup>a</sup>	1.32±0.02 <sup>f</sup>	1.21±0.01 <sup>a</sup>
	<b>Initial status</b>	<b>7.02</b>	<b>0.102</b>	<b>1.38</b>	<b>1.19</b>

\*Values with different superscripts differ significantly

The experimental results in Table-4 gives us a full overview of the effect of various organic treatments on chemical properties of soil. According to the study, various organic amendments have significantly influenced the soil parameters and the availability of various nutrients has improved after application of different organic treatments except the treatment that didn't receive any organic input. The data revealed that treatment T<sub>5</sub> (75% VC+ Azotobacter+ PSB+ KSB) resulted in highest available N (220.13 kg/ha), P (30.24 kg/ha) and K (222.16 kg/ha), respectively. This was followed by treatment T<sub>7</sub> (75% FYM+ Azotobacter+ PSB+ KSB) with available N (219.41 kg/ha), P (29.52 kg/ha) and K (216.24 kg/ha), respectively. Likewise, among sole organic manures T<sub>1</sub> (100% vermicompost) recorded maximum available N (213.13 kg/ha), P (26.15 kg/ha) and K (209.93 kg/ha), respectively. Among sole organic manures, T<sub>1</sub> (100% vermicompost) was followed by T<sub>3</sub> (100% farmyard manure) with available N (212.96 kg/ha), P (25.94 kg/ha) and K (208.75 kg/ha), respectively. Significantly lowest available N (198.52 kg/ha), P (21.12 kg/ha) and K (202.15 kg/ha) was recorded in treatment T<sub>9</sub> (RFD).

**Table-4. Effect of different organic amendments on nutrient availability of soil**

S.No	Treatment details	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
T <sub>1</sub>	<b>100%vermicompost @ 7.5t ha<sup>-1</sup></b>	213.13±0.03 <sup>c</sup>	26.15±0.03 <sup>c</sup>	209.93±0.01 <sup>c</sup>
T <sub>2</sub>	<b>100% poultry manure @ 8.3t ha<sup>-1</sup></b>	211.35±0.03 <sup>b</sup>	23.44±0.02 <sup>b</sup>	206.14±0.04 <sup>b</sup>
T <sub>3</sub>	<b>100% farmyard manure @ 24.9t ha<sup>-1</sup></b>	212.96±0.01 <sup>d</sup>	25.94±0.03 <sup>d</sup>	208.75±0.02 <sup>d</sup>
T <sub>4</sub>	<b>100% sheep manure @ 21.43 t ha<sup>-1</sup></b>	212.05±0.02 <sup>c</sup>	24.81±0.01 <sup>c</sup>	207.82±0.01 <sup>c</sup>
T <sub>5</sub>	<b>75% vermicompost @ 5.62 t ha<sup>-1</sup> + Azotobacter+ PSB+KSB</b>	<b>220.13±0.02<sup>i</sup></b>	<b>30.24±0.03<sup>i</sup></b>	<b>222.16±0.02<sup>i</sup></b>
T <sub>6</sub>	<b>75% poultry manure @ 6.24 t ha<sup>-1</sup> + Azotobacter+PSB+ KSB</b>	215.56±0.02 <sup>f</sup>	27.15±0.03 <sup>f</sup>	216.24±0.03 <sup>f</sup>
T <sub>7</sub>	<b>75% farmyard manure @ 18.7 t ha<sup>-1</sup> + Azotobacter+ PSB+KSB</b>	219.41±0.01 <sup>h</sup>	29.52±0.02 <sup>h</sup>	220.34±0.02 <sup>h</sup>
T <sub>8</sub>	<b>75% sheep manure @ 16.07 t ha<sup>-1</sup> + Azotobacter+PSB+ KSB</b>	217.65±0.03 <sup>g</sup>	28.44±0.02 <sup>g</sup>	219.45±0.02 <sup>g</sup>
T <sub>9</sub>	<b>RFD@ (150 kg N, 120 kg P, 90 kg K/ ha) (Control)</b>	198.52±0.02 <sup>a</sup>	21.12±0.02 <sup>a</sup>	202.15±0.03 <sup>a</sup>
	<b>Initial status</b>	<b>210.50</b>	<b>22.75</b>	<b>205.20</b>

\*Values with different superscripts differ significantly

The data pertaining to uptake presented in Table-5 revealed significant influence of various applied treatments. Among different treatments, treatment T<sub>9</sub> (RFD) has recorded maximum uptake of N (82.85 kg/ha), P (18.86.12 kg/ha) and K (87.96 kg/ha) which was significantly superior to all other treatments followed by treatment T<sub>5</sub> (75% VC+ Azotobacter+ PSB+ KSB) with N,P and K uptake of 79.17 kg/ha, 17.52kg/ha and 85.94 kg/ha, respectively. However, treatment T<sub>2</sub> (100% PM) recorded minimum nitrogen uptake of N (70.04 kg/ha), P (12.08 kg/ha) and K (79.35 kg/ha). In case of sole application of organic manures maximum uptake of N (72.94 kg/ha), P (14.73 kg/ha) and K (81.74 kg/ha) was recorded in treatment T<sub>1</sub> (100% VC).

**Table-5. Effect of different organic amendments on plant nutrient uptake in coloured capsicum**

S.No	Treatment details	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
T <sub>1</sub>	<b>100%vermicompost @ 7.5t ha<sup>-1</sup></b>	72.94±0.02 <sup>d</sup>	14.73±0.03 <sup>d</sup>	81.74±0.02 <sup>d</sup>
T <sub>2</sub>	<b>100% poultry manure @ 8.3t ha<sup>-1</sup></b>	70.04±0.02 <sup>a</sup>	12.08±0.01 <sup>a</sup>	79.35±0.02 <sup>a</sup>
T <sub>3</sub>	<b>100% farmyard manure @ 24.9t ha<sup>-1</sup></b>	71.55±0.03 <sup>c</sup>	13.93±0.01 <sup>c</sup>	81.08±0.01 <sup>c</sup>

T <sub>4</sub>	<b>100% sheep manure @ 21.43 t ha<sup>-1</sup></b>	70.87±0.02 <sup>b</sup>	13.10±0.01 <sup>b</sup>	80.55±0.02 <sup>b</sup>
T <sub>5</sub>	<b>75% vermicompost @ 5.62 t ha<sup>-1</sup> + Azotobacter+ PSB+KSB</b>	79.17±0.03 <sup>h</sup>	17.52±0.02 <sup>h</sup>	85.94±0.02 <sup>h</sup>
T <sub>6</sub>	<b>75% poultry manure @ 6.24 t ha<sup>-1</sup> + Azotobacter+PSB+ KSB</b>	73.51±0.01 <sup>e</sup>	15.45±0.02 <sup>e</sup>	82.11±0.02 <sup>e</sup>
T <sub>7</sub>	<b>75% farmyard manure @ 18.7 t ha<sup>-1</sup> + Azotobacter+ PSB+KSB</b>	75.63±0.02 <sup>g</sup>	16.93±0.02 <sup>g</sup>	84.14±0.04 <sup>g</sup>
T <sub>8</sub>	<b>75% sheep manure @ 16.07 t ha<sup>-1</sup> + Azotobacter+PSB+ KSB</b>	74.12±0.02 <sup>f</sup>	16.07±0.02 <sup>f</sup>	83.14±0.02 <sup>f</sup>
T <sub>9</sub>	<b>RFD@ (150 kg N, 120 kg P, 90 kg K/ ha) (Control)</b>	<b>82.85±0.02<sup>i</sup></b>	<b>18.86±0.03<sup>i</sup></b>	<b>87.96±0.01<sup>i</sup></b>

\*Values with different superscripts differ significantly

## Discussion

For nutrients like nitrogen and phosphorus to be available for plants in the soil, soil pH should be between 6.0 and 7.0 for pepper crop. At lower pH, Phosphorus forms insoluble compounds with Fe and Al making it unavailable for plant uptake. The decrease in soil pH in the treatments receiving either full or a part of nutrients through organic manures is due to release of various organic acids, especially carbonic acid during the decomposition process which might have resulted in lowering of pH. These results are in close conformity with Thornsby *et al.* (2000), Tarun *et al.* (2006), Chattoo (2006) and Mufti *et al.* (2017). Further the increase in electrical conductivity in treatment T<sub>5</sub> (75% vermicompost+ Azotobacter + PSB + KSB) is because of the fact that the decomposition of organic manures induces an acidic condition in soil which results in more solubility of salts. Thus, the salts present in soil become more mobile and conducts more electric current which results in increase in electrical conductivity. These results corroborate with Sharma *et al.* (2003), Chattoo (2006) and Mufti *et al.* (2018). Further, the addition of organic manure in treatment T<sub>5</sub> (75% vermicompost + Azotobacter + PSB + KSB) which recorded maximum OC results in modification of soil texture and the biological activity of the soil also got enhanced. The increase of organic carbon content may be due to improved microbial activities in the root zone which decomposed organic manures and also fixed unavailable form of mineral nutrients into available forms in soil thereby substantiated crop requirements and improved organic carbon level and stabilized soil pH. These results are in close conformity with Choudhary *et al.* (2011) and Mufti *et al.* (2018).

Reduced bulk density indicates better aeration and drainage besides good soil physical condition that would help in better root penetration and proliferation necessary for vigorous growth and subsequent high yield of crops. The reduction in bulk density by treatment T<sub>2</sub> (100% poultry manure) which recorded minimum bulk density of 1.22 g/cm<sup>3</sup> may be due to the improvement of aggregation and structure which has direct influence on the bulk density

of the soil. Similar findings were reported by Adeleye *et al.* (2010).

The treatment T<sub>5</sub> (75% VC+ Azotobacter+ PSB+ KSB) recorded more available N, P and K may be due to better and efficient decomposition, mineralization, solubilization of phosphorus and potassium compounds found in complexes, fixed and unavailable form in soil brought by action of phosphorus and potassium solubilizing bacteria. These results are in conformity with findings of Parthasarathi *et al.* (2007), Zakara (2009) and Jaipua *et al.* (2011). Further, the data pertaining to N, P and K uptake revealed significant influence of various treatments on uptake of nitrogen, phosphorus and potassium. Among different treatments, treatment T<sub>9</sub> (RDF) has recorded maximum uptake of N, P, and K may be attributed to the more availability of nutrients, since the nutrients are applied in chemical form only. These results are in conformity with the findings of Shilpa (2016).

### Conclusion

The soil parameters *viz.*, EC and organic carbon and the soil analysis revealed maximum availability of N, P, K were observed to be the increased by T<sub>5</sub> treatment (75% vermicompost + Azotobacter + PSB + KSB) over initial soil status. However, soil pH was slightly decreased by T<sub>5</sub> (75% vermicompost + Azotobacter + PSB + KSB) over other treatments and also bulk density was recorded minimum in T<sub>2</sub> (100% poultry manure). The same treatment T<sub>5</sub> (75% vermicompost + Azotobacter + PSB + KSB) also resulted in improved nutrient availability of major nutrients after the harvest of the crop. However, maximum nitrogen uptake of 82.85 kg/ha, phosphorus uptake of 18.86 kg/ha, and potassium uptake of 87.96 kg/ha was found in treatment T<sub>9</sub> (RDF) than other treatments. Therefore, Bio-fertilizers in combination with organic manures showed beneficial effect on soil health by way of improving the soil structure, soil texture, water retention capacity, and nutrient status like available N, P, K. Furthermore, organic manures and bio-fertilizers release nutrients slowly, minimizing nutrient runoff and leaching. Thus, by using these materials, nutrients are returned to the soil in a natural cycle, reducing the need for external inputs and improving nutrient use efficiency.

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