Integrated organic nutrient management in a smart multilayer cropping system: effects on yield and sustainability

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Abstract

Agriculture production systems are increasingly challenged by shrinking landholdings, declining soil fertility and the growing demand for sustainable food production. Multilayer farming has emerged as an efficient approach to maximize resource utilization and enhance productivity through the cultivation of crop with different canopy structures and rooting patterns within the same land unit. The present investigation was undertaken to design and establish multilayer cropping system comprising papaya, ridge gourd, tomato, spinach and turmeric under integrated organic Nutrient management.

The experiment was conducted in a Randomized block design with nine treatments and three replications. The multilayer arrangement consisted of papaya as the upper canopy crop, ridge ground as the vertical climbing crop, tomato as the middle-layer crop, spinach as the ground layer crop and turmeric as the underground crop, various combinations of farmyard manure, vermicompost, poultry manure, azotobacter and phosphate-solubilizing bacteria were evaluated for their influence on crop productivity, the results revealed that integrated application of organic manures and biofertilizers significantly improved the yield of all component crops. Treatment T8 comprising Poultry Manure (5t/ha^{-1}), vermicompost(5t/ha^{-1}), farmyard manure (10t/ha^{-1}), Azotobacter and phosphate solubilizing bacteria recorded the highest yields of tomato (42.85 t/ha^{-1}) and ridge gourd (25.30t/ha^{-1}), spinach (18.05 t/ha^{-1}), turmeric(27.25t/ha^{-1}) and papaya (55.80 t/ha^{-1}). The study demonstrated that smart multilayer farming integrated with organic nutrient management can effectively but use available resources and improve overall productivity under precision farming useful strategy for increasing agricultural productivity, profitability and resource use efficiency particularly for small and marginal farmers.

Keywords: Smart Multilayer farming, crop diversification, integrated nutrient management, organic manures, biofertilizers, sustainable agriculture.

1. Introduction

Agriculture plays a fundamental role in ensuring food security, livelihood generation and economic development throughout the world but increasing population pressure, declining per capita land availability, climate variability, degradation of natural resources and rising production costs have created significant challenges for agricultural sustainability. The demand for food is expected to increase substantially in the coming decades, necessitating innovative farming systems capable of producing higher yields from limited land resources while maintaining environmental quality and long term productivity.

Conventional monocropping systems have contributed significantly to food production during the past century but these systems often utilize natural resources inefficiently and associated with several ecological and economic limitations. Continuous cultivation of a single crop frequently results in nutrient depletion, deterioration of soil health, increased pest and disease incidence and reduced biodiversity. Furthermore monocropping system expose farmers to greater production and market risks due to dependence on a single commodity. These challenges have encouraged production systems capable of improving resource use efficiency and enhancing farm profitability.

Multilayer farming is an advanced form of diversified agriculture in which crops of varying heights, canopy structures, growth durations and rooting patterns are cultivated simultaneously within the same field. The system is based on the principle of efficient utilization of vertical and horizontal space through strategic arrangement of compatible crops, in multilayer farming, crop occupy different of sunlight soil nutrients, water and atmospheric resources. The system is particularly suitable for regions where agricultural land is limited and farmers seek to maximize productivity per unite area.

One of the major advantages of multilayer farming is improved utilization of solar radiation in conventional cropping systems a considerable portion of incoming sunlight remains unutilized because of the uniform canopy structure of single crop in contrast multilayer farming creates a vertically stratified canopy where tall crops intercept direct sunlight while medium and low growing crops utilize filtered and diffused radiation such an arrangement improves photosynthetic efficiency and increases total biomass production the cultivation of crops at different canopy levels thereby contributes to greater productivity and resource use efficiency.

Crop diversification in multilayer systems also contributes to ecological sustainability by enhancing biodiversity improving soil health reducing pest and disease incidence and minimizing production risks and cultivation of multiple crops with different growth durations ensures continuous production and income generation throughout the year.

Nutrient management is key factor influencing the success of multilayer farming systems. Organic nutrient source such as farmyard manure, vermicompost, poultry manure and biofertilizers improve soil fertility nutrient availability, microbial activity and crop productivity, biofertilizers such as azotobacter and phosphate solubilizing bacteria further enhance nutrient uptake through biological nitrogen fixation and phosphorus solubilization the crop growth yield and soil health more effectively than individual nutrient sources.

Although multilayer farming and organic nutrient management have been studied independently limited information is available on papaya ridge gourd- tomato-spinach-turmeric based multilayer cropping systems and evaluate the effect of integrated organic nutrient management on productivity of components crops.

Objective:

To design and establish a multilayer cropping system comprising papaya, ridge gourd, tomato, spinach and turmeric for efficient resource utilization and enhanced productivity.

2 Materials and methods

2.1Experimental site

The present investigation entitled “Design and establishment of papaya, ridge gourd, tomato, spinach, turmeric based multilayer cropping system under integrated organic nutrient management” was conducted during the year 2024-25. The experiment was undertaken to evaluate the performance of a multilayer cropping system integrating fruits, vegetable, leafy vegetable and spice crops under different organic nutrient management practices.

The experimental field was prepared following standard agronomic practices. all cultural operations including land preparation, sowing, transplanting, nutrient application, irrigation and intercultural operations were carried out as per recommended practices for individual crops. This study was designed to maximize utilization of vertical space, sunlight, nutrients and moisture through strategic arrangement of crop occupying different ecological niches.

2.2 Experimental design

The experiment was laid out in Randomized Block Design (RBD) Comprising nine treatments replicated three times.

Experiment design	:	**RBD**
Number of replications	:	3
Number of treatments	:	9
Total number of plots	:	27
Net Plot Size	:	3.00 x 1.0 m
Replication border	:	1.0 m
Plot border	:	0.5 m

The randomized block design was adopted to minimize experimental error and improve precision in treatment comparison.

2.3 Multilayer farming system layout

The multilayer farming system was designed based on crop height, canopy architecture, rooting depth, growth duration and resource requirements. Five crops were integrated within the same production unit to maximize utilization of sunlight, nutrients, water and space.

Upper canopy layer

Papaya (Pusa delicious) was established as the upper canopy crop due ti its upright growth habit and perennial nature.

Vertical layer

Ridge Gourd (Arka Sumeet) was established as the upper canopy crop due to its upright growth habit and perennial nature.

Middle layer:

Tomato (Arka Rakshak) occupied the intermediate canopy layer and utilized filtered sunlight beneath the papaya canopy.

Ground Layer

Spinach (Pusa Jyoti) was grown as low- growing leafy vegetable crop occupying the soil surface layer.

Underground layer

Turmeric (Rajendra Sonia) was cultivated as a rhizomatous crop utilizing underground soil resources. The arrangement ensured efficient utilization of ecological resources while minimizing component among component crops.

2.4 Crop Details

Tomato

Particulars	Details
Variety	Arka Rakshak
Date of sowing	07/10/2024
Date of transplanting	08/11/2025
Row Spacing	60cm
Plant spacing	45cm

Ridge Gourd

Particulars	Details
Variety	Arka Sumeet
Date of sowing	07/10/2024
Row Spacing	200cm
Plant spacing	60cm

Spinach

Particulars	Details
Variety	Pusa Jyot
Date of sowing	07/10/2024
Row Spacing	25cm
Plant spacing	10cm

Turmeric

Particulars	Details
Variety	Rajendra Sonia
Date of Planting	07/10/2024
Row Spacing	45cm
Plant spacing	25cm

Papaya

Particulars	Details
Variety	Pusa Delicious
Date of sowing	08/11/2024
Row Spacing	180cm
Plant spacing	180cm

2.5 Treatment Details

Nine treatment combinations consisting of organic manures and biofertilizers were evaluated.

Symbol	:	Details of treatments
T1	:	PSB+ FYM (20t/ha)
T2	:	Azotobacter + FYM (20t/ha)
T3	:	Azotobacter + PSB+ FYM (20t/ha)
T4	:	Vermicompost (5t/ha) +FYM (10t/ha)
T5	:	PSB + Azotobacter + Vermicompost (10t/ha)
T6	:	Poultry manure (10 t/ha) + Azotobacter + PSB
T7	:	Poultry manure (5 t/ha) + Azotobacter + PSB+ Vermicompost (5t/ha)
T8	:	Poultry manure (5 t/ha) + Azotobacter + PSB+ Vermicompost (5t/ha) + FYM (10t/ha)
T9	:	Control

2.6 Crop Management Practices.

All crops were established following recommended agronomic practices. Land preparation involved ploughing, harrowing and levelling to obtain a fine tilth. Organic manures were incorporated into soil before planting according to treatment specifications.

Papaya seedlings were transplanted at the designated spacing and served as the primary canopy crop. Ridge gourd was provided with trellis support for vertical growth and tomato seedlings were transplanted in rows beneath the ridge gourd canopy spinach was

sown directly in the designated ground layer while turmeric rhizomes were planted in the underground layer.

Irrigation was provided uniformly to all treatments but required, weeding, intercultural operations and plant protection measure were carried out according to standard recommendations.

3.Results and Discussion

3.1 Establishment of Smart Multilayer Farming System

The multilayer farming system comprising papaya, ridge gourd, tomato, spinach and turmeric was successfully established through strategic vertical arrangement of crops according to their growth habit, canopy structure, rooting pattern and duration. The system was designed to maximize utilization of available resources including sunlight, nutrients, moisture and growing space.

Papaya served as the upper canopy crop and formed the primary structural component of the system. Ridge gourd was trained vertically on support structures, enabling efficient utilization of aerial space. Tomato occupied the middle layer beneath the ridge gourd canopy, while spinach was cultivated as ground-layer crop. Turmeric occupied the underground layer and utilized subsurface soil resources.

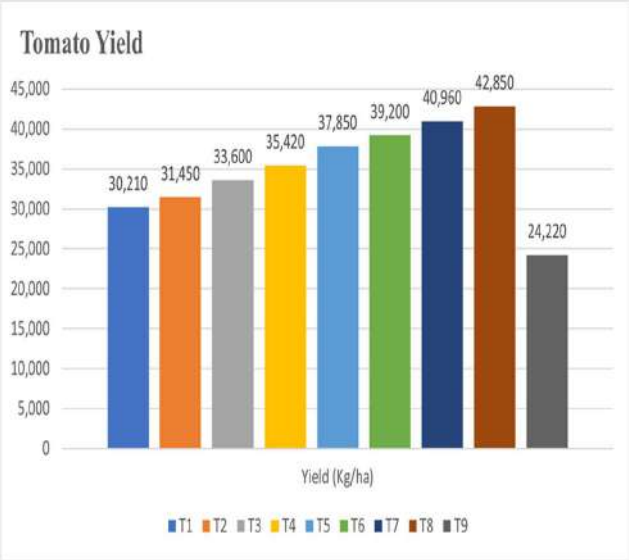
The arrangement enabled simultaneous cultivation of fruit, vegetables, leafy vegetables, and spice crops with in the same production unit. Such vertical stratification minimized direct competition among components crops and facilitated efficient utilization of ecological resources. The system also provided opportunities for diversified production and staggered harvesting throughout the cropping period.

The successful establishment of the multilayer farming system demonstrated the compatibility of papaya, ridge gourd, tomato, spinach and turmeric under integrated organic nutrient management conditions.

3.2 Effect of Organic Nutrient Management on Tomato Yield

Table 1. Effect of Different Organic Nutrient Management Treatments on Tomato Yield

Treatment	Yield (kg ha^{-1})
T1	30,210
T2	31,450
T3	33,600
T4	35,420
T5	37,850
T6	39,200
T7	40,960
T8	42,850
T9	24,220



The results revealed considerable variations in tomato yield among different nutrients management treatments. The highest yield of 42,850 kg ha^{-1} was recorded under treatment T8, followed by T7 (40,960 kg ha^{-1}) and T6 (39,200 kg ha^{-1}). The lowest yield was observed in the control treatment (T9) with 24,220 kg ha^{-1}.

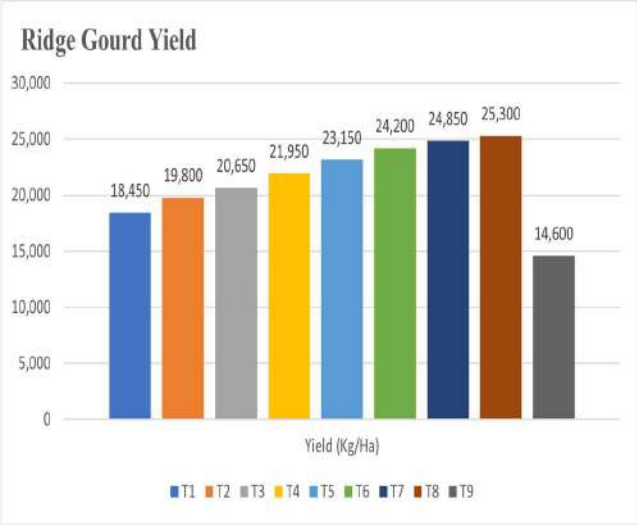
The superior performance of T8 may be attributed to the combined application of poultry manure, vermicompost, farmyard manure, azotobacter and phosphate solubilizing bacteria, which improved nutrient availability, microbial activity and soil fertility. Organic nutrient sources supplied essential nutrients gradually throughout the crop growth period, resulting in improved vegetative growth, flowering and fruit development.

Treatments receiving combinations of organic manures and biofertilizers consistently outer performed treatments receiving individual nutrient sources. The results indicate the importance of integrated organic nutrient management in improving tomato productivity with in the multilayer farming systems.

3.3 Effect of Organic Nutrient Management on Ridge Gourd Yield.

Table 2 Effect of Different Organic Nutrient Management Treatments on Ridge Gourd Yield

Treatment	Yield (Kg/Ha)
T1	18,450
T2	19,800
T3	20,650
T4	21,950
T5	23,150
T6	24,200
T7	24,850
T8	25,300
T9	14,600



The yield of ridge gourd increased progressively with improvement in nutrient management. Treatment T8 recorded the maximum yield of 25,300 kg ha^{-1}, followed by T7 (24,850 kg ha^{-1}) and T6 (24,200 kg ha^{-1}). The minimum yield was recorded under the control treatment T9 (14,600 kg ha^{-1}).

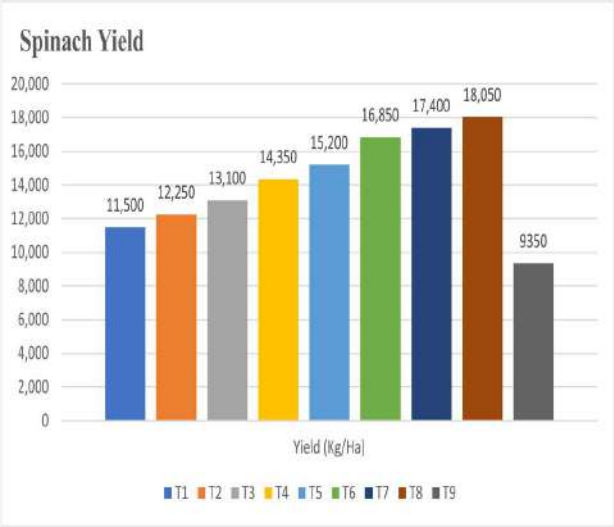
The increase in yield under integrated nutrient management treatments may be attributed to improve nutrient supply, enhanced microbial activity and better soil physical properties. Organic manures improved moisture retention and nutrient availability, while biofertilizers enhanced nutrient mobilization and uptake. These factors collectively promoted vigorous vegetation growth and higher fruit production.

3.4 Effect of organic nutrient management on spinach yield

TABLE 4. Effect of Different Organic Nutrient Management Treatments on Spinach Yield

Treatment	Yield (Kg/Ha)
T1	11,500

T2	12,250
T3	13,100
T4	14,350
T5	15,200
T6	16,850
T7	17,400
T8	18,050
T9	9350



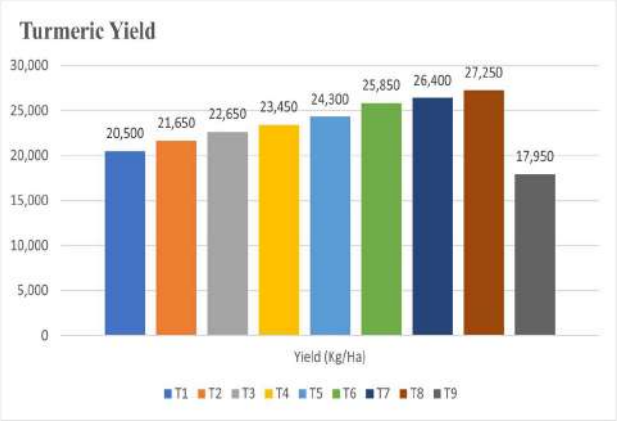
Significant differences in spinach yield were observed among treatments. Treatment T8 produced the highest yield of 18,050 kg ha^{-1}, followed by T7 (17,400 kg ha^{-1}) and T6 (16,850 kg ha^{-1}). The lowest yield was recorded under the control treatment (9,350 kg ha^{-1})

The superior performance of integrated nutrient management treatments may be attributed to increase nutrient availability and improved soil biological activity. Leafy vegetables respond rapidly to nutrient supply, and the combined application of organic manures and biofertilizers provided a balanced nutrient environment for continuous leaf production. The results indicated the integrated nutrient management is highly beneficial for spinach cultivation within multilayer systems.

3.5 Effect of Organic Nutrient Management on Turmeric Yield

Table 3 Effect of Different Organic Nutrient Management Treatments on Turmeric Yield

Treatment	Yield (Kg/Ha)
T1	20,500
T2	21,650
T3	22,650
T4	23,450
T5	24,300
T6	25,850
T7	26,400
T8	27,250
T9	17,950



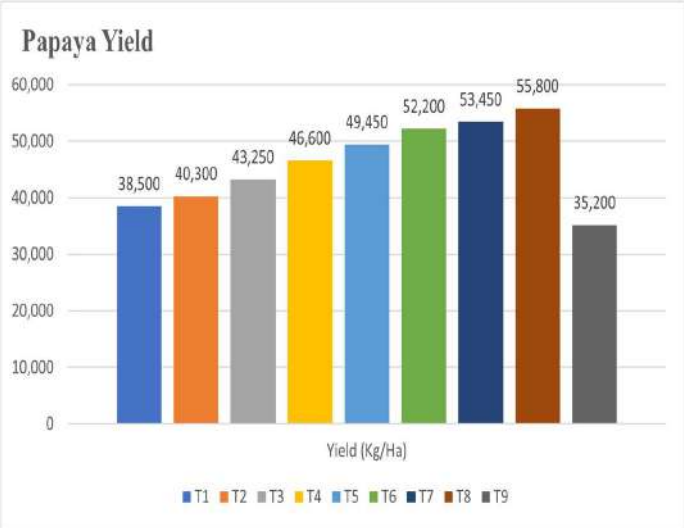
The yield of turmeric was significantly influenced by nutrient management treatments. The highest yield (27,250 kg ha^{-1}) was recorded under treatment T8 followed by T7 (26,400 kg ha^{-1}) and T6 (25,850 kg ha^{-1}). The control treatment recorded the lowest yield (17,950 kg ha^{-1}).

Turmeric responds favourably to organic nutrient sources because of its long growth duration and high nutrient requirement. Organic manures improved soil structure and nutrient availability, while biofertilizers enhanced nutrient mobilization. Consequently, integrated nutrient management treatments produced higher rhizome yields compared with individual nutrient applications.

3.6 Effect of Organic Nutrient Management on Papaya Yield

Table 4 Effect of Different Organic Nutrient Management Treatments on Papaya Yield

Treatment	Yield (Kg/Ha)
T1	38,500
T2	40,300
T3	43,250
T4	46,600
T5	49,450
T6	52,200
T7	53,450
T8	55,800
T9	35,200



Papaya exhibited a positive response to integrated nutrient management. Treatment T8 recorded the maximum yield of 55,800 kg ha^{-}, followed by T7 (53,450 kg ha^{-1}) and T6 (52,200 kg ha^{-1}). The lowest yield was observed under the control treatment (35,200 kg ha^{-1})

The higher yield recorded under T8 may be attributed to sustained nutrient release from organic manures and enhanced nutrient availability through biofertilizers activity.

Improved soil health and nutrient uptake likely contributed to greater fruit development and overall productivity.

3.7 Comparative Productivity of Component Crops

Table 5. Highest Yield Recorded by Component Crops

Crop	Highest Yield (Kg Ha^{-1})
PAPAYA	55,800
TOMATO	42,850
TURMERIC	27,250
RIDGE GOURD	25,300
SPINACH	18,050

Among all component crops, papaya recorded the highest yield under integrated nutrient management, followed by tomato, turmeric, ridge gourd and spinach. The results indicated that all crops responded positively to organic nutrient management practices.

The multilayer farming system successfully accommodated five different crops within the same production unit and demonstrated the feasibility of diversified crop production. The productivity achieved across all crop's layers indicated effective utilization of available growing space and resources.

3.8 Effect of Integrated Organic Nutrient Management in Multilayer Farming System

A consistent trend was observed across all component crops, wherein integrated nutrient management treatments produced higher yields than individual nutrient sources and control treatment. Treatments T8 recorded the highest yield in tomato, ridge gourd, spinach, turmeric and papaya, indicating the superiority of combined organic nutrient management.

The positive response may be attributed to complementary effects of farmyard manure, vermicompost, poultry manure, Azotobacter and phosphate-solubilizing bacteria. Organic manures improved soil physical properties, enhanced nutrient availability and increased microbial activity, while biofertilizers contributed to biological nitrogen fixation and phosphorus solubilization.

The results clearly demonstrate that integrated organic nutrient management plays an important role in improving productivity within multilayer farming systems. The combined use of organic manures and biofertilizers was ore effective that the application

of individual nutrient sources and offers a sustainable approach for enhancing crop production.

4. Conclusion

The present investigation successfully demonstrated the design and establishment of a multilayer cropping system comprising papaya, ridge gourd, tomato, spinach and turmeric under integrated organic nutrient management. The multilayer arrangement enabled the simultaneous cultivation of fruit, vegetable, leafy vegetable, and spice crops within the same production unit through efficient utilization of vertical and horizontal space.

The results revealed that all components crop responded positively to the application of organic manures and biofertilizers. Among the various nutrient management treatments, treatment T8 consisting of poultry manure (5 t ha^{-1}), vermicompost (5 t ha^{-1}) and farmyard manure (10 t ha^{-1}), Azotobacter and phosphate solubilizing bacteria consistently recorded the highest yield across all crops. The maximum yields obtained under T8 were 42,850 kg ha^{-1} in tomato, 25,300 kg ha^{-1} in ridge gourd, 18,050 kg ha^{-1} in spinach, 27,250 kg ha^{-1} in turmeric, and 55,800 kg ha^{-1} in papaya.

The superior performance of integrated nutrient management treatments may be attributed to improved nutrient availability, enhanced microbial activity better soil physical properties, and sustained nutrient release throughout the crop growth period. The combined application of organic manures and biofertilizers proved more effective than individual nutrient sources in improving crop productivity.

The study further demonstrated that the papaya-ridge gourd-tomato-spinach- turmeric based multilayer farming system is a practical and sustainable production model capable of increasing productivity while promoting crop diversification. The integrated of organic nutrient sources within the multilayer system provides an environmentally friendly approach to agriculture production and contributes to long-term soil fertility and sustainability.

Based on the findings of the present investigation, it may be concluded that smart multilayer farming integrated with organic nutrient management offers considerable potential for enhancing agricultural productivity and promoting sustainable farming practices, particularly under conditions of limited land availability.

Reference

Altieri, M. A. (2015). Agroecology: The science of sustainable agriculture. CRC Press.

Francis, C. A. (1986). Multiple cropping systems. Macmillan Publishing Company, New York.

Kamilaris, A., & Prenafeta-Boldú, F. X. (2018). Deep learning in agriculture: A survey. *Computers and Electronics in Agriculture, 147*, 70–90. https://doi.org/10.1016/j.compag.2018.02.016

Liakos, K. G., Busato, P., Moshou, D., Pearson, S., & Bochtis, D. (2018). Machine learning in agriculture: A review. *Sensors, 18*(8), 2674. https://doi.org/10.3390/s18082674

Lithourgidis, A. S., Dordas, C. A., Damalas, C. A., & Vlachostergios, D. N. (2011). Annual intercrops: An alternative pathway for sustainable agriculture. *Australian Journal of Crop Science, 5*(4), 396–410.

McBratney, A., Whelan, B., Ancev, T., & Bouma, J. (2005). Future directions of precision agriculture. *Precision Agriculture, 6*, 7–23. https://doi.org/10.1007/s11119-005-0681-8

Mohanty, S. P., Hughes, D. P., & Salathé, M. (2016). Using deep learning for image-based plant disease detection. *Frontiers in Plant Science, 7*, 1419. https://doi.org/10.3389/fpls.2016.01419

Pierce, F. J., & Nowak, P. (1999). Aspects of precision agriculture. *Advances in Agronomy, 67*, 1–85. https://doi.org/10.1016/S0065-2113(08)60513-1

Willey, R. W. (1979). Intercropping—Its importance and research needs. Part 1. Competition and yield advantages. *Field Crop Abstracts, 32*, 1–10.

Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M. J. (2017). Big data in smart farming – A review. *Agricultural Systems, 153*, 69–80. https://doi.org/10.1016/j.agsy.2017.01.023

Zhang, N., Wang, M., & Wang, N. (2002). Precision agriculture—A worldwide overview. *Computers and Electronics in Agriculture, 36*(2–3), 113–132. https://doi.org/10.1016/S0168-1699(02)00096-0

Aulakh, M. S., Benbi, D. K., & Pasricha, N. S. (2005). Integrated nutrient management for sustainable crop production. *Nutrient Cycling in Agroecosystems, 71*, 185–197. https://doi.org/10.1007/s10705-004-6394-6

Bhattacharyya, P., Roy, K. S., Neogi, S., Adhya, T. K., Rao, K. S., & Manna, M. C. (2012). Effects of organic amendments on soil health and crop productivity. *Archives of*

Agronomy and Soil Science, 58(7), 723–735. https://doi.org/10.1080/03650340.2010.545699

Edmeades, D. C. (2003). The long-term effects of manures and fertilizers on soil productivity and quality. *Nutrient Cycling in Agroecosystems, 66*, 165–180. https://doi.org/10.1023/A:1023999816690

Ghosh, P. K. (2004). Growth, yield, competition and economics of groundnut-cereal fodder intercropping systems. *Field Crops Research, 88*(2–3), 227–237. https://doi.org/10.1016/j.fcr.2004.01.015

Mäder, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P., & Niggli, U. (2002). Soil fertility and biodiversity in organic farming. *Science, 296*(5573), 1694–1697. https://doi.org/10.1126/science.1071148

Palm, C. A., Myers, R. J. K., & Nandwa, S. M. (1997). Combined use of organic and inorganic nutrient sources for soil fertility maintenance. *Replenishing Soil Fertility in Africa*, 193–217.

Subba Rao, N. S. (2001). Biofertilizers in agriculture and forestry (4th ed.). Oxford & IBH Publishing Co., New Delhi.

Vessey, J. K. (2003). Plant growth promoting rhizobacteria as biofertilizers. *Plant and Soil, 255*, 571–586. https://doi.org/10.1023/A:1026037216893

Yadav, R. L. (2003). Assessing on-farm efficiency and economics of fertilizer use in rice–wheat systems. *Field Crops Research, 81*(1), 39–51. https://doi.org/10.1016/S0378-4290(02)00194-5