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Research Article

ORGANIC AND INTEGRATED NUTRIENT MANAGEMENT FOR SUSTAINABLE BANANA PRODUCTION

TAMULI PHUKAN PURABI

Department of Horticulture, Assam Agricultural University, Jorhat, Assam 785013, India
*Corresponding Author: Email-tamuliphukanpurabi@gmail.com

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Abstract- Banana is a gross feeder crop and exhausts large quantities of nutrient from the soil and requires a continuous replenishment. The excess applications of inorganic fertilizers lead to nutrient imbalances, inefficiency and environmental pollution while inadequate application of nutrients causes soil fertility depletion which drives the use of organic nutrient sources alone or in combination with inorganic fertilizers. Organic food production is a holistic system which promotes and enhances soil fertility and biological diversity as well as improving quality of fruit. Therefore, to eliminate both over and inadequate applications of inorganic fertilizers, use of organic and integrated nutrient management is best alternative for sustainable crop production and maintenance of soil fertility.

Keywords- Banana, Organic, Integrated nutrient management, Sustainable crop production, Soil fertility.

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Introduction

Banana (*Musa* spp.) is one of the most important commercial fruit crops especially in the tropics and has a high consumer demand worldwide. Being an exhaustive crop requires proper manuring and fertilizer application for good growth and development, which mostly comes from inorganic chemical sources. The intensive use of chemical fertilizers increased the quantity of the food produced but decreased the "nutritional quality" and "soil fertility" over the years. For sustainable soil productivity, it is very crucial to maintain a balance in soil biological activity, as any disturbance will affect the nutrient transformation in soil. Nowadays, attention has been turned to the use of organic fertilizer sources alone and in combination with chemical fertilizers, not only to improve yields but also to maintain and improve the soil physical, chemical, and biological properties. Organic nutrient management includes organic manure as well as bio-fertilizer are an economically attractive and ecologically sound means of reducing chemical fertilizer and promote soil health by building organic matter content, increasing aeration, and enhancing microbial abundance and diversity besides improving the quality and quantity of production. Integrated nutrient management is the concept of combine use of organics (i.e. manure, compost, bio fertilizers, green manure, crop residues, etc), and inorganic fertilizers to improve the quality and quantity of production besides enhancing the sustainability and health of the soil. Therefore, literature relevant to the subject has been reviewed.

Effect of Organic and Integrated Nutrient Management on Growth, Yield and Quality of Banana

Organic and Integrated nutrient management is vital for sustainable food production. Integrated nutrient management refers to maintenance of soil fertility and plant nutrient supply to an optimum level for sustaining the desired crop productivity and fruit quality through optimization of benefits from all possible sources in an integrated manner. Use of organic manure, bio-fertilizers and green manures alone or in combination with inorganic fertilizers has been found effective in improving and maintaining sustainability and health of the soil, increasing nutrient use efficiency so maximizing the productivity of banana.

Effect on Growth of Banana

Inoculation of Azospirillum in combination with the nitrogenous fertilizer enhanced the height (261.75 cm) and girth (64.10 cm) of pseudostem, leaf production and leaf area in banana *cv.* Poovan. It also reduces the time interval between the productions of successive leaves i.e., Phyllochron [1]. [2] reported that 25% FYM + 75% inorganic fertilizers (RDF 200 g N, 50 g P_2O_5 and 200 g K_2O per plant) not only produced taller plant but also shortened the time required for emergence of bunch of banana *cv.* Basarai. It observed that 75% recommended NPK + 2 kg vermicompost per plant recorded the minimum number of days (236.30) for shooting and shortened the crop duration by 13.2 days over inorganic fertilizers alone in banana *cv.* Rajapuri [3]. It reported that plant treated with banana compost with 50 or 25 per cent chemical fertilizers (NPK) + sulphur has recorded higher plant height in Maghrabi banana [4]. The application of 80 per cent recommended NPK (200:50:400 g NPK/plant) + 15 kg poultry manure per plant recorded maximum growth parameters like plant height, pseudostem girth, total number of leaves and total leaf area and followed by application of rice husk ash @ 15 kg/plant + 80 per cent recommended NPK and press mud 15 kg/plant + 80 per cent recommended NPK in ratoon of Poovan banana [5]. Application of VAM combined with in situ vermin-culture has registered highest plant height, girth, number of leaves and leaf area in banana *cv.* Rajapuri [6]. The experiment on integrated nutrient management for tissue culture banana *cv.* Grand Naine revealed that maximum plant height (216.0 cm), pseudostem girth (70.92 cm), minimum days required to flower (258.5 days) and crop duration (356.9 days) were recorded with application of 100% recommended dose of NPK (200:40:200 g NPK/plant) with 10 Kg FYM per plant and bio fertilizer (Azospirillum and PSB) @ 25 g per plant [7]. Highest pseudostem height, pseudostem girth, total number of leaves, days taken to shooting and less number of days for harvesting with application of 20 kg FYM + 1 kg neem cake + 200:40:200 g NPK per plant [8]. conducted an experiment to study the effect of integrated nutrient

management on growth and yield of banana *cv*. Jahaji and found that there was significant increase in pseudostem height, girth, total leaf area, number of functional leaves and shortening of the crop cycle with application of 100 percent recommended dose of NPK (100 g N, 33 g P_2O_5, 330 g K_2O per plant) in combination with farm yard manure @ 12 kg per plant and bio fertilizer (Azospirillum and PSB) @ 50 g per plant [9]. The application of 100 per cent recommended dose of fertilizer i.e. 165:52.5:495 g NPK/plant along with 40% Wellgro soil has recorded the significantly thicker pseudostem girth, maximum number of leaves and registered shorter crop duration in banana *cv*. Grand Naine 10]. Study the effect of organic fertilizer and organic fertilizer plus chemical fertilizer on growth, yield and quality of Kamphaeng Phet Emperor banana and found that treatment comprising 20 kg/plant chicken manure + 250 g/plant 16-16-16 fertilizer had highest plant growth in terms of plant height, pseudostem circumference, leaf number/plant, sucker number/plant [11]. The treatment received 50% recommended dose of inorganic fertilizers, 12.5 kg farmyard manure, 3 kg vermicompost, 1kg neem cake, 100 g VAM and 50 g each of Phosphobacteria and Azospirillum per plant recorded significantly lesser phyllochron (7.62 days), early flowering (252.41 days), early maturity and reduced total crop duration in *cv*. Poovan [12]. The treatment T_{10} with the combined application of organic manures, amendments and green manures (Farmyard manure @ 10 kg + Neem cake @ 1.25 kg + Vermicompost @ 5 kg and Wood ash @ 1.75 kg /plant + Triple green manuring with Sunhemp + Double intercropping of Cow pea + bio-fertilizers *viz*., Arbuscular Mycorrhizae @ 25 g , Azospirillum @ 50 g, Phosphate Solubilizing Bacteria @ 50 g and Trichoderma harzianum @ 50 g/plant) registered the maximum pseudostem height (218.00 cm), pseudostem girth (69.53 cm), number of leaves (14.56) and LAI (3.79) in banana *cv*. Grand Naine [13]. Experiment revealed that application of 80% RDF + 20% RDN through vermicompost + biofertilizers *viz*., 50 g *Azospirillum*, 50 g Phosphate solubilising bacteria (PSB) and 25 g potassium mobilising bacteria (KMB) (*Frateuriaaurantia*) per plant has resulted in the highest plant height at 3 MAP (129.67 cm) and 5 MAP (184.29 cm) and maximum pseudostem girth at 3 MAP (35.61 cm) and 5 MAP (49.74 cm) whereas application of 80% RDF + 20% RDN through farmyard manure + biofertilizers *viz*., 50 g Azospirillum, 50 g PSB and 25 g KMB per plant has registered maximum retention of functional leaves at 3 MAP (10.58) and at shooting (15.75) and maximum leaf area (3.87 m^2) at 3 MAP [14]. Plants treated with FYM + Neem cake + 50% RDF + Azotobactor + PSB (T_{19}) resulted in higher plant height (3.61 m), number of leaves (17.0), pseudostem diameter (50.50 cm), length of leaf (161.80 cm), leaf breadth (63.93 cm), phyllochron (7days), root growth (12.6 cm) [15]. 75 per cent recommended dose of fertilizer (RDF) + 25 per cent vermicompost was the best treatment combination that resulted in maximum plant height (116.30 cm), plant girth (37.43 cm), number of leaves per plant (13.00), number of suckers per plant (6.93), sucker height (27.17 cm) and number of leaves per sucker (9.50) in banana *cv*. Rasthali [16]. Treatment T_{10} containing organic manure (FYM 10 kg + Neem cake 1.25 kg + Vermicompost 5 kg + Wood ash 1.75 kg/pl), green manures (Triple green manuring with dhaincha + Cowpea + Cowpea as intercrop) and biofertilizers and biocontrol agents (AM (25 g) + *Azospirillum* (50 g) + PSB (50 g) + *T. harzianum* (50 g)/pl) recorded maximum pseudostem height (117.02 cm), pseudostem girth (51.76 cm), leaf area index (LAI) (3.63), total number of leaves (25.50), and shortest duration for shooting (271.25) as well as shooting-harvesting interval (99.50 days) among the organic treatments in banana *cv*. Dwarf Cavendish (AAA) [17].

Effect on Yield of Banana

Inoculation of Azospirillum in combination with the nitrogenous fertilizer positively influenced the bunch characters of banana *cv*. Poovan. The increased bunch weight (8.3-13.1%) over control was also found associated with a corresponding increase in length of bunch, number of hands, length, girth and weight of fingers [1]. Obtained highest banana yield of 74.6, 83.3 and 73.7 t per ha for plant crop, first ratoon and second ratoon respectively when cow pea was grown as a green manure crop and the required NPK was applied in combination of 25 per cent through FYM and remaining 75 per cent through straight fertilizers [2]. The maximum number of fingers per bunch (8.01), bunch weight (5.20 kg /bunch) and fruit yield (16.05 t /ha) were recorded with application of 75% RDF (180:108:225 g NPK per plant) + vermicompost 2 kg per plant in Rajapuri banana. [18] noted that application of 3 g /plant Azospirillum and FYM along with 75 per cent of N and 100 per cent P and K had produced the maximum bunch weight of 15.30 kg in hill banana *cv*. Virupakashi [3]. Plants treated with banana compost in combination with 50 per cent chemical fertilizer (NPK) + 25 per cent sulphur improved the bunch characteristics (length, circumference, number of fingers and finger weight) in Maghrabi banana [4]. Studied the effect of different organic manure with graded levels of inorganic fertilizers on ratoon of Poovan banana and reported that the maximum bunch weight (21.73 kg) was observed at 80 per cent recommended NPK + 15 kg poultry manure per plant and the minimum bunch weight (12.79 kg) was recorded at 40 per cent recommended NPK (recommended NPK 200:50:400 g /plant) without any organic manure. It was also found that nearly 20 percent of NPK can be saved by adding either 15 kg poultry manure or 15 kg rice husk ash per plant to produce 18.5 percent more yield than at 100 percent NPK + no organic manure in ratoon of Poovan banana [5]. Recorded highest banana fruit yield of 32.41 t/ ha with an application of AM fungi inoculated plants supplemented with 75% recommended dose of fertilizers and vermi compost, whereas 29.34 t/ ha yield was recorded in vermicompost with 75% RDF [19]. Application of vermicompost along with 75% RDF produced significantly maximum yield in both plant and ratoon crop in banana *cv*. Rajapuri (AAB) [20].] The application of 75 percent RDN and RDP (200:90:200 g NPK/plant) along with Azotobacter and PSM each at 2.4 g/plant and vermicompost @ 2 kg/plant recorded higher yield per plant (21.74 kg) with higher number of hand per bunch (9.95), number of finger per bunch (161.92), finger weight (157.76 g), finger length (23.31 cm) and finger girth (13.25 cm) [21]. The experiment conducted during 2001-2002 in Arabhavi, Karnataka reported that highest finger weight (84.85 g), finger girth (3.80 in diameter), finger length (13.06 cm), pulp to peel ratio (3.04) and yield (26.81 t/ha) were recorded in treatment consisting of 25% RDN as farmyard manure + green manure (sunhemp) at 25 kg/acre + 75% inorganic RDNin banana *cv*. Rajapuri (AAB) [22]. [7] revealed that combined application of 100% recommended dose of NPK (200:40:200 g NPK per plant) along with 10 kg FYM per plant and biofertilizers (*Azospirillum* and PSB @ 25 g per plant each) were found better for producing maximum hand per bunch (9.47), bunch weight (17.21 kg/plant) and yield (76.5 t/ha) in banana *cv*. Grand Naine. [23] reported that maximum bunch weight and fruit yield was obtained by applying 200 g N + 150 g P_2O_5 + 200 g K_2O per plant combined with organic booster slurry @ 6 litre per plant in Ardhapuri banana. [24] reported that application of 100 % RDF + Azospirillum (50 g/plant) + PSB (50 g/plant) + VAM (250 g/plant) + Trichodermaharzianum (50 g/plant) recorded highest hands/ bunch, fingers/ bunch, bunch weight (kg), finger length (cm), finger girth (cm) and yield (t/ha). [9] studied the integrated nutrient management in banana *cv*. Jahaji and found that the application of 100 percent recommended dose of NPK (110-33-330 g NPK/plant) + FYM @ 12 kg/plant + Azospirillum and PSB @ 50 g/plant significantly increased bunch weight (16.50 kg/plant), number of hands per bunch (9.32), finger per hand (23.04) and yield (73.96 t/ha).A field experiment was conducted during 2009-2010 to assess the effect of integrated nutrient management with different combination of organic, inorganic and bio fertilizer for tissue cultured Grand Naine banana in Mizoram condition and they indicated that yield characters such as number of finger per hand, finger length, finger volume and weight of finger were significantly increases with application of 100% RDF (200-100-300 g NPK/plant) with VAM, Azospirillum, PSB and Trichoderma harzianum @ 50 g/plant [25]. [26] carried out an experiment to study effect of chemical fertilizer and vermicompost on yield and nutrient content and uptake in fruit of banana *cv*. Grand Naine. The highest yield, nutrient content and uptake by fruit of banana were recorded with the application of full recommended dose and 8 kg of vermicompost. To see the effect of organic manures/ chemical fertilizers on yield and quality of banana *cv*. Basrai and found that treatment having 10 kg FYM + 180 g N in organic form (castor cake) + 90 g P_2O_5 + 180 g K_2O/plant recorded significantly the highest bunch yield of 17.50 kg per plant [27]. Observed higher number of hands and fingers per bunch along with highest bunch weight and yield with the supplementation of vermicompost enriched with urea @ 10kg per plant to banana *cv*. Nendran [28]. It found that the application of 100%-

recommended dose of fertilizer along with 40% wellgro soil recorded maximum number of hands (10.2 and 10.3), number of finger (136.3 and 145.2), bunch weight (23.9 and 25.3 kg/plant) and total yield (72.8 and 77.1 t/ha) during year 2010-11 and 2011-12 , respectively [10]. [12] from their experiment reported that treatment received 50% recommended dose of inorganic fertilizers, 12.5 kg farmyard manure, 3 kg vermicompost, 1.0 kg neem cake, 100 g VAM and 50 g each of Phosphobacteria and Azospirillum per plant show significantly highest bunch weight (22.25 kg) as a result of medium number of hands (12.78), more finger weight (96.80 g), larger fruit size (14.75 cm) and maximum peel to pulp ratio (4.83%). [29] found that application of FYM @ 10kg per plant + neem cake @ 1.25kg per plant + vermicompost @ 5kg per plant + wood ash @ 3.75kg per plant has recorded a yield of 73.15 t per ha in banana *cv*. Grand Naine**.** [13] reported that the treatment T_{10}containing farmyard manure @ 10 kg + Neem cake @ 1.25 kg + Vermicompost @ 5 kg and Wood ash @ 1.75 kg /plant + Triple green manuring with Sun hemp + Double intercropping of Cow pea + biofertilizers *viz.,* Arbuscular Mycorrhizae @ 25 g , Azospirillum @ 50 g, Phosphate Solubilizing Bacteria @ 50 g and Trichoderma harzianum @ 50 g/plant) registered the maximum yield (27.96 Kg/plant), finger weight (280.25 g), pulp weight (194.13 g) and peel weight (65.27 g) in banana *cv*. Grand Naine. [14] from their experiment revealed that application of 80% RDF + 20% RDN through farmyard manure + biofertilizers *viz*., 50 g Azospirillum, 50 g PSB and 25 g KMB per plant has registered maximum number of hands per bunch (10.75), fruits per bunch (156.50), fruit girth (14.37 cm), bunch weight (24.53 kg) and fruit yield (68.02 t per ha)) in banana *cv*. Grand Naine.[17] reported that treatment T_{10} containing organic manure (FYM 10 kg + Neem cake 1.25 kg + Vermicompost 5 kg + Wood ash 1.75 kg/pl), green manures (Triple green manuring with dhaincha + Cowpea + Cowpea as intercrop) and biofertilizers and biocontrol agents (AM (25 g) + Azospirillum(50 g) + PSB (50 g) + Trichodermaharzianum (50 g)/pl) recorded maximum fruit yield (46.80 t/ha), bunch weight (14.00 kg), hands per bunch (7.50), fingers per hand (17.11), and weight of second hand (2.75 kg) among the organic treatments in banana *cv*. Dwarf Cavendish (AAA).

Effect on Quality of Banana

The experiment conducted on integrated nutrient management in banana *cv*. Basarai under high density plantation and found that higher TSS (22.18 ^{0}Brix), ascorbic acid (12-32 mg/100 g), reducing sugar (8.16 %), total sugar : acidity ratio (82.68) with lower acidity (0.17 %) were registered when application of 75 percent RDN and RDP (200:90:200 g NPK/plant) along with Azotobacter and PSM each at 2.4 g/plant and vermicompost @ 2 kg/plant [21].[30] observed higher level of TSS (26.0%) with the application of 25% FYM +75% inorganic N as urea over the control (RDN alone 200 g N/plant) in banana *cv*. French Plantain (AAB). [31] noted an increase in finger length and diameter, TSS, minimum titrableacidity and maximum total sugar content in the fingers of banana plants *cv*. Grand Naine with the application of 100 per cent RDF of NPK + 50g Azospirillum + 50g PSB + 50g Trichoderma harzianum per plant in banana *cv*. Grand Naine. [29] noted an increase in TSS, reducing and non - reducing sugars along with total sugar content in Grand Naine banana with the application of FYM @ 10kg per plant + neem cake @ 1.25kg per plant + vermicompost @ 5kg per plant + wood ash @ 3.75kg per plant. [32] from their experiment revealed that the combined application of fertigation and consortium of biofertilizers significantly enhanced the quality attributes *viz.,* total sugars, reducing and non reducing sugars, acidity and TSS: Acid ratio. The treatment of 100% recommended dose of fertilizer through fertigation (RDFTF) with 300 g of consortium of biofertilizers (CBF) recorded significantly higher total sugars, reducing and non reducing sugars, TSS: Acid ratio apart from reducing the acidity followed by fertigation with 75% recommended dose of fertilizers along with consortium of biofertilizers as compared to 100% recommended dose of fertilizers through soil (RDFTS) in both main and ratoon crops of banana *cv*. Robusta (AAA). [17] revealed that treatment T_{10} containing organic manure (FYM 10 kg + Neem cake 1.25 kg + Vermicompost 5 kg + Wood ash 1.75 kg/pl), green manures (Triple green manuring with dhaincha + Cowpea + Cowpea as intercrop) and biofertilizers and biocontrol agents (AM (25 g) + *Azospirillum*(50 g) + PSB (50 g) + *T. harzianum* (50 g)/pl) recorded highest TSS (23.40%), reducing sugar (9.10%), non reducing sugar (10.11%) and total sugar (19.21%) and lowest titrable acidity (0.22%) in banana *cv*. Dwarf Cavendish (AAA).

Conclusion

The literature reviewed in this paper relevant to banana nutrition is definitely useful for sustainable banana production as it provides broad and clear information regarding the beneficial effect of inorganic, organic and bio fertilizers in banana plant. Organic sources of nutrients ensuring sustainable crop production as it do not cause any serious soil health problems and thereby ensure food security and protect the environment.

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Abbreviations: NPK: nitrogen, phosphorus, and potassium

Conflict of Interest: None declared

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