**Response of Integrated Dose of Plant Nutrients to Vegetative and Reproductive Growth and Yield of Tissue Cultured Banana**

 **Abstract**

To assess the response of integrated dose of plant nutrients to vegetative and reproductive growth and yield of tissue cultured banana(*Musa paradisiaca* L.) var. Grand Naine, a field experiment was conducted at Horticulture Garden, Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (Uttar Pradesh), India, during the cropping season 2019-2020. The experiment was laid out in randomized block design using three replications and eleven treatments*viz.,*T1-100% RDF of NPK (110 + 30 + 330g NPK), T2-75% RDF of NPK + 50g *Azotobacter + 50g PSB + 50g T. harzianum*, T3-50% RDF of NPK + 50g *Azotobacter + 50g PSB + 50g T. harzianum*, T4-25% RDF of NPK + 50g *Azotobacter + 50g* PSB *+ 50g T. harzianum*, T5-75% RDF of N + 100% RDF of PK + 50g *Azotobacter +50g* PSB *+* 50g *T. harzianum*, T6-50% RDF of N + 100% RDF of PK + 50g *Azotobacter + 50g* PSB *+ 50g T. harzianum*, T7-75% RD of K + 100% RDF of NP + 50g *Azotobacter + 50g* PSB *+* 50g *T. harzianum*, T8-50% RD of K + 100% RDF of NP + 50g *Azotobacter + 50g* PSB *+* 50g *T. harzianum*, T9-75% RDF of P + 100% RDF of NK + 50g *Azotobacter + 50g* PSB *+ 50g T. harzianum,* T10-50% RDF of P + 100% RDF of NK + 50g *Azotobacter + 50g* PSB *+* 50g *T. harzianum* and T11-Control (without any fertilizers). Results obtained from the present study clearly showed that plants supplied with 75% Recommended dose Fertilizer of NPK (Nitrogen, Phosphorus and Potash) + 50g *Azotobacter + 50g* Phosphate solubilizing bacteria  + 5*0g Trichoderma harzianum*, produced the highest pseudostem height (158.64cm), girth (71.26cm), total number of leaves (35.10), number of functional leaves (18.12), length of inflorescence (120 cm), minimum number of days from planting to flowering (251), number of days from flowering to harvesting (95.33), with maximum bunch weight (26.75 kg), number of fingers per bunch (176.05), number of hands per bunch (8.66), number of fingers per hand (20.33), finger weight (154.18 g), finger length (21.66 cm), finger diameter (16.50 cm) and yield (66.87 t/ha).

**Keywords**: Banana, Grand Naine, INM, NPK, *Azotobacter*, PSB and *Trichoderma harzianum*.

**Introduction**

“Banana (*Musa species*) is an important commercial fruit crop in tropical and sub-tropical regions of the world. The fruits are very delicious and sweet in taste. It is a staple food for millions of people all around the world. In India, bananas are grown in different states under different climatic conditions” (Butani *et al.*, 2012). “In India, bananas are grown in other states under various climatic conditions. In the world of fruits, banana is a complete food fruit packed with all the necessary energy and health-giving elements. On account of these properties combined with delicious taste and flavour, it is in great demand in fresh as well as processed forms all over the world and has gained commercial popularity in the international fruit trade” (Hazarika *et al.*, 2000). “Banana is a monocotyledonous, perennial herb within the order Zingiberales and the family *Musaceae*. The *Musaceae* is divided into two genera: *Musa* and *Ensete*. *Musa* comprises about 40 species and is distributed through India, New Guinea, Australia and South East Asia” (Simmonds, 1962). “Integrated nutrient management (INM) is beneficial for maintaining soil fertility and plant nutrient supply to an optimum level for sustaining crop productivity through optimization of benefits from all possible sources of plant nutrients in an integrated manner. It was found that the early vegetative phase of growth of banana, especially up to the 3rd/6th month after transplanting and the bunch development stage is the critical stages of banana at which yield is affected” (Prameela, 2010). The current practice for Integrated Nutrient Management combines organic inputs (compost, manure) with chemical fertilizers for sustainability. The proposed treatments aim to enhance nutrient efficiency, reduce environmental impact, and improve banana quality and yield with biofertilizers and organic amendments that enhance soil microbiome activity to improve nutrient availability naturally.

Implementing integrated nutrient management combined with biofertilizer applications and chemical fertilizers will improve nutrient use efficiency, reduce environmental impacts, and enhance banana yield and quality compared to traditional fertilization practices.

**Materials and methods**

Tissue-cultured plants of banana cultivar Grand Naine were brought from the Government Tissue Culture Unit, Lucknow and planted in the Horticulture Garden, Department of Fruit Science, C.S. Azad University of Agriculture and Technology, Kanpur (Uttar Pradesh), India. The site falls under the sub-tropical climate in Indo-Gangetic central plains having alluvial soil and is located between 25º26’ to 26º28’ North latitude and 79º31’ to 80º34’ East longitude at an elevation of 125.90 meters above mean sea level. The experimental place, Kanpur is characterized between the semi and sub-tropical climate with hot, dry summers and cold winters. The normal rainfall of the locality is about 750-1000 mm per annum. The maximum temperature ranges between 20º to 38ºC and minimum from 8.0º to 26ºC with a relative humidity of 45-85% in different months of the year. The planting was done at a spacing of 2 × 2 m. The experiment was laid out in randomized block design using three replications and eleven treatments. Observations on pseudostem height, girth, total number of leaves, number of functional leaves, length of inflorescence, number of days from planting to flowering, number of days from flowering to harvesting, bunch weight, number of fingers per bunch, number of hands per bunch, number of fingers per hand, finger weight, finger length finger diameter and yieldt/ha. Other intercultural operations like weeding, earthing up, desuckering, propping, irrigation, insect-pest and disease management were done during crop production, which is common in all treatments. The data were analyzed using the method suggested by Panse and Sukhatme (1967).

**Result and discussion**

**Height and girth of pseudostem:** Data presented in Table 1 revealed that various treatments differed significantly regarding height and girth of pseudostem. The height and girth of pseudostem were increased significantly with integrated doses of nutrients and bio-fertilizers. The maximum height (158.64 cm) and girth (71.26 cm) of pseudostem was obtained with the application of 75% RDF of NPK + 50g *Azotobacter* + 50g PSB + 50g T. *harzianum* per plant. The height and girth of pseudostems were reduced with the reduction in doses of different levels of chemical and bio-fertilizers, and they were under control at the minimum (125.78 and 51.80 cm, respectively). The increase in height and girth of pseudostem might be due to the improvement of physical properties of soil, higher nutrient uptake and increased activity of micro-organisms, which were manifested in the form of enhanced growth and higher carbohydrate production as explained by Hazarika and Ansari (2010) and Nayyer et al. (2014) in banana. These investigations get the support of Tripathi (2017) in banana, Dutta *et al.* (2010) in papaya and Tripathi et al. (2010) in strawberry.

**Total number of leaves and functional leaves per plant: The total number of and number of functional leaves per plant at the time of inflorescence emergence were increased significantly with** integrated doses of nutrients and bio-fertilizers (Table 1). The maximum number of leaves and number of functional leaves per plant (35.10 and 18.12, respectively) at the time of emergence of inflorescence were produced in the plants treated with 75% RDF of NPK + 50g *Azotobacter + 50g PSB + 50g T. harzianum* per plant, whereas, the minimum number of leaves and number of functional leaves per plant at the time of emergence of inflorescence (23.16 and 10.12, respectively) were recorded in plants which were kept under control (T11) without any treatment. The increase in vegetative growth and other parameters might be due to the production of more chlorophyll content with the inoculation of nitrogen fixers. The increased number of leaves and number of functional leaves might have increased due to the increased photosynthetic activity, resulting in a higher accumulation of carbohydrates. These findings are in complete agreement with those of Hazarika and Ansari (2010)**,** Gogoi *et al.* (2004) and Tripathi (2017) in banana.

**Length of inflorescence:** The maximum length of inflorescence (120.00 cm) was recorded in the plants which were fertilized with 75% RDF of NPK + 50g *Azotobacter + 50g PSB + 50g T. harzianum* per plant. However, the minimum length of inflorescence (91.33 cm) was recorded in the plants under control (T11). This phenomenon may be due to the prolonged growth of plants in the presence of NPK, Azotobacter,and PSB*.* These findings are in accordance with the reports of Hazarika and Ansari (2010), Nayyer *et al.* (2014) and Tripathi (2017) in banana.

 **Number of days from planting to flowering**: The minimum number of days taken from planting to flowering were recorded in the plants which were treated with 75% RDF of NPK + 50g *Azotobacter + 50g PSB + 50g T. harzianum* per plant (251.00 days), whereas, the maximum number of days (267.66 days) taken for flowering were recorded in control (T11) Table 1. The earliness in flowering might be due to the simultaneous transport of growth substances like cytokinin to the auxiliary bud, breaking the apical dominance. These results are in agreement with the findings of Hazarika and Ansari (2010) Nayyer *et al.* (2014) and Tripathi (2017)in banana.

**Number of days from flowering to harvesting:** the minimum number of days (95.33 days) taken from flowering to harvesting were recorded in the plants which were treated with 75% RDF of NPK + 50g *Azotobacter + 50g PSB + 50g T. harzianum* per plant. However, the maximum number of days (125.00 days) taken from flowering to harvesting was recorded in control plants (T11). These results are in agreement with the findings of Nayyer *et al.* (2014) and Tripathi (2017) in banana, Tripathi *et al.* (2010), Singh and Singh (2009) in strawberry, which also got advanced duration of harvesting (earliness) by approximately one month which obviously extended the period of harvesting.

**Number of fingers per bunch, number of hands per bunch and number of fingers per hand:** The maximum number of fingers per bunch (176.05), number of hands per bunch (8.66), number of fingers per hand (20.33) and was recorded when the plants were fertilized with 75% RDF of NPK + 50g *Azotobacter + 50g PSB + 50g T. harzianum* closely followed by 75% RDF of N + 100% RDF of PK + 50g *Azotobacter +50g PSB +* 50g *T. harzianum* (168.74 and 8.45, 19.97 respectively). However, the minimum number of fingers per bunch (104.29), number of hands per bunch (6.66) and fingers per hand (15.66) were recorded under T11-control (Table 2). This increase in number of fingers per hand and per bunch may be due to the fact that bio-fertilizers, *i.e.* nitrogen fixers, not only increased the availability of nitrogen to the plant roots but also increased their translocation from root to flower through plant foliage (Singh and Singh, 2009) and ultimately increase the number of fingers. These findings are in agreement with the finding of Hazarika and Ansari (2010), Nayyer *et al.* (2014) and Tripathi (2017) in banana, who also obtained higher numbers of fingers per bunch and per hand with the application of 75% RDF of NPK + 50g *Azotobacter + 50g PSB + 50g T. harzianum*.

**Finger weight and Bunch weight:** The maximum weight of fingers (154.18 g) and bunch (26.75 Kg) was recorded in the plants fertilized with the 75% RDF of NPK + 50g *Azotobacter + 50g PSB + 50g T. harzianum* (T2) followed by 75% RDF of N + 100% RDF of PK + 50g *Azotobacter +50g PSB +* 50g *T. harzianum* (149.27 g and 25.18 Kg, respectively), treated plants whereas the minimum weight of fingers (110.84 g) and bunch (11.55 Kg) was recorded from the untreated control plants (T11) (Table 2). Relatively higher amounts of carbohydrates could have promoted the growth rate of bunch size and in turn increased the fingers and bunch weight. These findings are in line with the findings of Patel *et al.* (2018), Hazarika *et al.* (2011), Hazarika and Ansari (2010) and Chezhiyen *et al*. (1999) in banana. These findings are in line with the findings of Tripathi (2017), Nayyer *et al.* (2014) in banana, Tripathi *et al.* (2014), Tripathi *et al.* (2016) and Yashasvi *et al.* (2021) in strawberry.

**Finger length, finger diameter and Yield:** The finger length and diameter were significantly increased with the use of integrated doses of different nutrients with other bio-fertilizers. The maximum finger length (21.66 cm) and diameter (16.50) were recorded in the plants fertilized with 75% RDF of NPK + 50g *Azotobacter + 50g PSB + 50g T. harzianum* (T2) followed by 75% RDF of N + 100% RDF of PK + 50g *Azotobacter +50g PSB +* 50g *T. harzianum* (T5), whereas, the minimum finger length (9.00 cm) and diameter (11.20 cm) were recorded under control (Table 2). These results are in accordance with the findings of Hazarika *et al.* (2011) Nayyer *et al.* (2014) and Tripathi (2017), Panelo and Diza (2017) in banana. Maximum yield (66.87 t/h) recorded in 75% RDF of NPK + 50g *Azotobacter + 50g PSB + 50g T. harzianum* (T2). This increase in finger length and diameter might be due to the better filling of the fruits and their growth with increased uptake of nutrients from soil which has produced enough carbohydrates in the leaf for translocation to the sink for better filling of fruits. Similar results were also reported by Jeyabhaskaran *et al*. (2001) in banana.

**Conclusion**

It is concluded that plants fertilized with 75% RDF of NPK + 50g *Azotobacter* + 50g PSB + 50g T. *harzianum* per plant significantly increased the height of pseudostem, girth of pseudostem, total number of leaves, total number of functional leaves at the time of emergence of inflorescence, length of inflorescence, gave earliness in flowering and flowering to harvesting of bunch. Maximum weight of bunch with a higher number of fingers per plant also produced fingers of significantly maximum length, diameter, weight and yield with more benefits. In contrast, the minimum height of pseudostem, girth of pseudostem, total number of leaves, total number of functional leaves at the time of emergence of inflorescence, length of inflorescence, flowering and flowering to harvesting of bunch were recorded from the plants kept under control. So far as the quality characters of fingers are concerned 75% RDF of NPK + 50g *Azotobacter* + 50g PSB + 50g T. *harzianum* fertilized plants produced fingers with maximum TSS, total sugars, TSS: acid ratio, reducing sugars, non-reducing sugars, sugar: acid ratio, pulp percentage and more pulp/peel ratio, whereas, minimum titratable acidity and peel per cent were also found in 75% RDF of NPK + 50g *Azotobacter* + 50g PSB + 50g T. *harzianum* fertilized plants.

**Disclaimer**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (Chat GPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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**Table 1: Response of Tissue Cultured Banana (*Musa paradisiaca* L.) to Integrated Doses of Plant Nutrients (Part I)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **Pseudostem height at shooting (cm)** | **Pseudostem girth (cm)** | **Total number of leaves per plant** | **Number of functional leaves per plant** | **Length of inflorescence (cm)** | **Number of days from planting to flowering** | **Number of days from flowering to harvesting (Days)** |
| **T1** | 100% RDF of NPK (110 + 30 + 330g NPK)  | 135.48 | 58.46 | 29.76 | 13.81 | 104.33 | 260.33 | 101.33 |
| **T2** | 75% RDF of NPK + 50g *Azotobacter + 50g PSB + 50g T. harzianum*  | 158.64 | 71.26 | 35.10 | 18.12 | 120.00 | 251.00 | 95.33 |
| **T3** | 50% RDF of NPK + 50g *Azotobacter + 50g PSB + 50g T. harzianum*  | 146.31 | 60.82 | 30.81 | 14.72 | 107.66 | 259.66 | 99.66 |
| **T4** | 25% RDF of NPK + 50g *Azotobacter + 50g PSB + 50g T. harzianum*  | 126.80 | 59.78 | 25.84 | 11.24 | 93.33 | 265.33 | 115.00 |
| **T5** | 75% RDF of N + 100% RDF of PK + 50g *Azotobacter +50g PSB +* 50g *T. harzianum*  | 156.76 | 69.42 | 33.91 | 17.36 | 118.00 | 253.33 | 96.33 |
| **T6** | 50% RDF of N + 100% RDF of PK + 50g *Azotobacter + 50g PSB + 50g T. harzianum*  | 132.81 | 62.12 | 28.54 | 12.97 | 101.66 | 262.66 | 104.66 |
| **T7** | 75% RD of K + 100% RDF of NP + 50g *Azotobacter + 50g PSB +* 50g *T. harzianum*  | 149.76 | 65.20 | 30.87 | 16.48 | 113.33 | 257.00 | 97.33 |
| **T8** | 50% RD of K + 100% RDF of NP + 50g *Azotobacter + 50g PSB +* 50g *T. harzianum*  | 130.44 | 56.12 | 27.10 | 12.14 | 98.66 | 263.66 | 109.00 |
| **T9** | 75% RDF of P + 100% RDF of NK + 50g *Azotobacter + 50g PSB + 50g T. harzianum*  | 148.30 | 62.80 | 31.93 | 15.61 | 110.77 | 258.33 | 97.66 |
| **T10** | 50% RDF of P + 100% RDF of NK + 50g *Azotobacter + 50g PSB +* 50g *T. harzianum*  | 128.12 | 52.74 | 26.92 | 11.59 | 95.00 | 264.00 | 112.33 |
| **T11** | Control (without fertilizers and bio-fertilizers)  | 125.78 | 51.80 | 23.16 | 10.12 | 91.33 | 267.66 | 125.00 |
| **SEm±** | 5.16 | 2.14 | 1.15 | 0.64 | 3.40 | 3.28 | 1.38 |
| **CD at 5%** | 15.65 | 6.48 | 3.49 | 1.94 | 10.32 | 9.96 | 4.18 |

**Table 2: Response of Tissue Cultured Banana (*Musa paradisiaca* L.) to Integrated Doses of Plant Nutrients (Part II)**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **Number of fingers per bunch** | **Number of hands per bunch** | **Number of fingers per hand** | **Finger weight (g)** | **Finger length (cm)** | **Finger diameter (cm)** | **Bunch weight (kg)** | **Yield t/ha** |
| **T1** | 100% RDF of NPK (110 + 30 + 330g NPK)  | 141.28 | 7.81 | 18.09 | 128.84 | 14.66 | 13.50 | 18.20 | 45.50 |
| **T2** | 75% RDF of NPK + 50g *Azotobacter + 50g PSB + 50g T. harzianum*  | 176.05 | 8.66 | 20.33 | 154.18 | 21.66 | 16.50 | 26.75 | 66.87 |
| **T3** | 50% RDF of NPK + 50g *Azotobacter + 50g PSB + 50g T. harzianum*  | 147.71 | 7.95 | 18.58 | 134.39 | 16.33 | 14.06 | 19.89 | 49.47 |
| **T4** | 25% RDF of NPK + 50g *Azotobacter + 50g PSB + 50g T. harzianum*  | 113.65 | 7.02 | 16.19 | 113.78 | 9.66 | 12.03 | 12.93 | 32.32 |
| **T5** | 75% RDF of N + 100% RDF of PK + 50g *Azotobacter +50g PSB +* 50g *T. harzianum*  | 168.74 | 8.45 | 19.97 | 149.27 | 20.00 | 15.66 | 25.18 | 62.96 |
| **T6** | 50% RDF of N + 100% RDF of PK + 50g *Azotobacter + 50g PSB + 50g T. harzianum*  | 136.34 | 7.69 | 17.73 | 124.36 | 13.33 | 13.20 | 16.95 | 42.38 |
| **T7** | 75% RD of K + 100% RDF of NP + 50g *Azotobacter + 50g PSB +* 50g *T. harzianum*  | 161.61 | 8.25 | 19.59 | 145.52 | 18.66 | 15.03 | 23.51 | 58.79 |
| **T8** | 50% RD of K + 100% RDF of NP + 50g *Azotobacter + 50g PSB +* 50g *T. harzianum*  | 129.41 | 7.52 | 17.21 | 120.16 | 11.66 | 13.03 | 15.54 | 38.87 |
| **T9** | 75% RDF of P + 100% RDF of NK + 50g *Azotobacter + 50g PSB + 50g T. harzianum*  | 155.79 | 8.11 | 19.21 | 139.61 | 17.66 | 14.66 | 21.07 | 54.37 |
| **T10** | 50% RDF of P + 100% RDF of NK + 50g *Azotobacter + 50g PSB +* 50g *T. harzianum*  | 122.33 | 7.33 | 16.69 | 116.26 | 10.33 | 12.66 | 14.22 | 35.55 |
| **T11** | Control (without fertilizers and bio-fertilizers)  | 104.29 | 6.66 | 15.66 | 110.84 | 9.00 | 11.20 | 11.55 | 28.89 |
| **SEm±** | 4.89 | 0.38 | 0.69 | 5.69 | 0.77 | 0.84 | 0.72 | 1.00 |
| **CD at 5%** | 14.82 | 1.15 | 2.09 | 17.26 | 2.34 | 2.56 | 2.19 | 3.03 |