

Original Research Article

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## Growth, Phosphorus Uptake and Yield of 'Robusta' Banana (*Musa xparadisiaca*) as Influenced by Dose and Placement of $^{32}\text{P}$ Labelled Single Super Phosphate

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### ABSTRACT

Growth, phosphorus uptake and bunch yield of banana cv. Robusta grown under high density planting were studied on a sandy clay loam (Udic Paleustalf) soil at ICAR-Indian Institute of Horticultural Research, Bangalore using  $^{32}\text{P}$  labelled super phosphate with application of three levels viz., 60, 80, and 100 per cent of recommended dose of phosphorus in three different placement viz., 15-35, 35-55 and 55-75 cm distance from pseudostem of the plant. The results on vegetative growth parameters revealed that the maximum plant height (212.4 cm) and girth (63.40 cm), highest number of functional leaves (16.3) and total leaves (29.70) and early flowering (295 days) and harvesting (431 days) were recorded with application of 100 per cent recommended dose of P at band width of 20 cm around the plant between 35 to 55cm. From the specific activity of  $^{32}\text{P}$  found in leaves, highest Pdff (12.26%), total P uptake (16.0 g plant<sup>-1</sup> and 71.13 kg ha<sup>-1</sup>) and fertilizer P uptake (1.96 g plant<sup>-1</sup> and 8.72 kg ha<sup>-1</sup>) were recorded with application of 100 per cent recommended dose of P fertilizers in the distance of 35-55 cm from the pseudostem of the experimental plant. Higher dry matter production (7.31 kg plant<sup>-1</sup> and 32.49 t ha<sup>-1</sup>), bunch weight (22.17 kg) and bunch yield (98.51 t ha<sup>-1</sup>) of 'Robusta' banana was recorded with 100% recommended phosphorus dose and found to be on par with 80% recommended phosphorus. Among the placements, the application of fertilizers between 35 and 55 cm distances yielded highest bunch weight, bunch yield and dry matter production. Application of fertilizer at the farthest distance between 55 and 75 cm distances was distinctly inferior showing that there is little scope of application of fertilizers between the rows under the high density planting of banana and it is best to apply fertilizer in a circular strips between 15 and 55 cm distances at 5 cm depth.

#### Keywords

Phosphorus, P uptake, Radiotracer, Bunch yield, Banana, Robusta

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## Introduction

Banana is the second most important fruit crop after mango in India. India is the largest producer of banana in the world, contributing 25.58 per cent to the global production of banana, with a total production of 29.7 million tonnes from an area of 0.82 million hectare with productivity of 37.0 tonnes per hectare (Indian Horticulture Database, 2017). The wide gap between production potential and realized productivity can be reduced by efficient crop, nutrient and water management practices (Mueller *et al.*, 2012). Banana crop with the fruit yield of 50 tonnes from one hectare removes, 320 kg N, 23 kg P and 925 kg K per every year. Besides major nutrients, other micronutrients are also essential for satisfactory production (Kalaivanan *et al.*, 2014). To maintain soil fertility and to permit continuous production, these nutrients must be replenished every year through manures and fertilizers (Bhalerao *et al.*, 2009; Ndabamenye *et al.*, 2013).

Phosphorus (P) is an indispensable plant nutrient and no plant on this planet can complete its life cycle without adequate supply of P. Phosphorus is one of the building blocks of all forms of life and every living cell requires it. Whereas agricultural production is limited in many areas by the lack of available P and excessive P inputs in other agro-ecosystems result in the pollution of surface waters (Frossard *et al.*, 2009). Furthermore, there are indications that the current reserves of rock phosphates that can be mined at a relatively low cost to be processed into fertilizers will be exhausted within the next century (Cordell *et al.*, 2009). India has very limited known resource of rock phosphate which is mostly low to medium grade in quality, thus making it almost entirely dependent on imports. Currently, exploitable reserves in India are present only in Rajasthan and Madhya Pradesh (Subba Rao *et al.*, 2015).

Phosphorus use must therefore become much more efficient in the future. Concepts and management practices for a better crop P use efficiency from soil or from fertilizer will be based on a better understanding and quantification of soil-plant processes at different spatial and temporal scales. In banana, phosphorus helps to produce healthy rhizome and a strong root system. It also influences vegetative growth in general and fruit set in particular.

Since fertilizer is a major input, studies on its management involving appropriate time and method of placement are great importance. Precise placement often improves the efficiency by which plants take up nutrients and consequently encourages maximum yields of intensively managed crops (Obreza and Sartain, 2010; Nkebiwe *et al.*, 2016). Fertilizer use efficiency is the key to achieve highest possible yield with a minimum fertilizer input. Radioactive tracers are useful in phosphorus research in banana under high density planting beyond conventional techniques as they give a direct and quantitative measure of isotope-labelled fertilizer nutrients utilized by the crop, quite independent of native nutrients present in the soil (Kotur, 2012).

Studies using the  $^{32}\text{P}$  tracer methodology on the P dynamics in the soil-plant system, mainly evaluating the efficiency of soluble phosphate fertilizers, have shown that the crops rarely utilize more than 10% of the applied amount (Franzini *et al.*, 2009; Nkebiwe *et al.*, 2016). The root feeding zone of banana and the effect of time and method of placement have been studied by several workers. But quantitative information regarding efficiency of absorption of fertilizer nutrients and fertilizer utilization under high density planting is lacking. The objective of the study, therefore, was to determine the effect of rate of application and the distance of placement from pseudo stem on growth, P

uptake and yield of banana cv. Robusta under high density planting using labelled super phosphate.

## **Materials and Methods**

### **Experimental site and design**

A field experiment was conducted to study the phosphorus uptake, fruit and bunch yield of banana under high density planting using tracer techniques with application of three levels of P fertilizers viz., 60, 80, and 100 per cent in three different placement viz., 15-35, 35-55 and 55-75 cm distance from pseudostem during the year 2008-2010 in the farm soil of ICAR - Indian Institute of Horticultural Research, Bangalore. The experimental site is situated in the latitude of 13°58' N and the longitude of 78°35' E with an elevation of 890 metres from mean sea level (MSL). Indian Institute of Horticultural Research (IIHR) enjoys tropical climate and receives an average annual rainfall of 891.5 mm with U.S.W.B class Pan Evaporation of 1468 mm. The mean annual temperature ranges from a minimum of 17.82°C to a maximum of 29.50°C. The experiment was conducted on a reddish brown sandy clay loam soil belonging to Thyamagondalu series (family Udic Paleustalf) with pH of 5.9, cation exchange capacity of 8.7 cmol (p<sup>+</sup>) kg<sup>-1</sup> soil, organic carbon of 3.0 g kg<sup>-1</sup>, available N of 246 kg ha<sup>-1</sup>, available P of 15.5 kg ha<sup>-1</sup> and available K of 180 kg ha<sup>-1</sup>.

A total of 9 treatments were replicated thrice in a randomized block design. The recommended dose of fertilizer (180 g of N, 105 g of P<sub>2</sub>O<sub>5</sub> and 225 g of K<sub>2</sub>O per plant) was applied to banana in three equal splits at early vegetative (8<sup>th</sup> leaf/65 DAP), late vegetative (16<sup>th</sup> leaf/115 DAP) and bud differentiation stages (165 DAP). Urea, <sup>32</sup>P labelled single superphosphate (with specific activity of 0.2 mCi/gP) and muriate of potash were used as

N, P and K sources, respectively and were applied in circular bands around the banana plants. A layout of single experimental plot consisting of main plant (labelled single super phosphate receiving plant), neighbour I and neighbour II is given in figure 1. Since measurable activity of <sup>32</sup>P persisted in the plant even after 100 days, two series of the crop were raised simultaneously. Series I' received first and third split application of <sup>32</sup>P labelled superphosphate while series II' received second split application of the labelled superphosphate. To ensure that all the experimental plants received the same dose of N, P and K, 'Series I' received the second split application using unlabelled (ordinary) single superphosphate.

### **Monitoring of <sup>32</sup>P activity or absorption of P by the plant**

The absorption of fertilizer P by banana plant was monitored by collecting middle 25 cm<sup>2</sup> of leaf lamina from both sides of the mid-rib from the third fully open leaf of banana at 20<sup>th</sup>, 40<sup>th</sup>, 60<sup>th</sup> and 80<sup>th</sup> day after application of labelled single superphosphate at each growth stage. The collected banana leaf samples were dried in hot air oven at 70°C. Then dried leaf samples were powdered and digested by using di-acid mixture of nitric (HNO<sub>3</sub>) and perchloric (HClO<sub>4</sub>) acids in the ratio of 9:4. The digested sample was then made up to 100 ml volume. From this, 15 ml was pipetted out to 50 ml plastic vial.

The <sup>32</sup>P activity or absorption of P in the digested sample was determined in Liquid Scintillation Counter through Cerenkov technique. Total P was determined in the diacid wet digest by the vanadomolybdate method. The phosphorus derived from fertilizer (% Pdf), fertilizer P uptake and fertilizer P utilization by banana was calculated as follows.

$$\text{Pdff (\%)} = \frac{\text{Specific activity of } ^{32}\text{P in the leaf sample}}{\text{Specific activity of } ^{32}\text{P in the fertilizer}} \times 100$$

**Fertilizer P uptake =**

$$\text{Total P uptake (kg/ha)} \times \frac{\text{Pdff}}{100}$$

$$\text{Fertilizer P utilization (\%)} = \frac{\text{Fertilizer P uptake}}{\text{Rate of P application}} \times 100$$

Average Pdff was calculated from the Pdff obtained at three different growth stages and used for calculating the fertilizer P uptake and fertilizer utilization. Total P uptake was calculated by multiplying P content in the entire plant with dry matter.

### **Observations on growth and yield of banana**

All observations on growth characters *viz.*, plant height, girth of pseudostem, number of leaves, number of functional leaves and days taken to 50 per cent flowering, shooting, shooting to harvesting and harvesting were recorded from treated plants in all three replications. Height of the plant at shooting stage was measured from above ground level upto the angle between the youngest first and second leaf axils. Girth of the plant was measured at 30 cm above the ground level at monthly intervals upto shooting. Total number of photosynthetically active leaves (functional leaves) produced by the plant was counted at monthly intervals till shooting. Photosynthetically active leaves were identified by seeing greenness of the leaves. The total number of leaves produced during the growth period of the crop was also recorded. The fruits were considered to be ready for harvest when the angular girth of

skin of the fruit disappeared, and colour turned from dark green to light green. Yield of banana in tonnes per hectare was calculated by multiplying the average bunch weight with the total number of plants per hectare.

### **Statistical analysis**

Data generated from the experimental plots were analyzed using SAS 9.3 version of the statistical package (SAS Institute Inc, 2011). Analysis of variance (ANOVA) was performed using SAS PROC ANOVA procedure. Means were separated using Fisher's protected least significant difference (LSD) test at a probability level of  $p < 0.05$ .

### **Results and Discussion**

#### **Plant height and Pseudostem girth**

Plant height and pseudostem girth are important attributes, which decide the reproductive growth of the plants. Plant height differed significantly among treatments at shooting stage (Table 1). In the present experiment, planting of single sucker per hill with application of 100 per cent recommended dose of phosphorus (RDP) at middle placement (35-55cm) resulted in maximum plant height of 212.4 cm during shooting stage. An increase in plant height with increasing plant population might be due to increased plant population per unit area, which provides less space for individual plant and in search of sunlight perhaps makes the plant upright resulting in tall growth. Similar kind of results was also reported in banana by Chaudhuri and Baruah (2010), Thippesha, (2004) and Nalina *et al.*, (2000). Pseudostem girth significantly differed among treatments at all stages of crop growth (Table 1). Thicker plant girth (63.4 cm) at shooting was observed in 100 per cent recommended phosphorus placed in a band width of 35-55 cm from the pseudostem of the plants, while 60 per cent

recommended phosphorus applied in a band width of 55-75 cm produced thinner plant girth (54.3 cm). Generally, the girth of the pseudostem reduced under high density planting (HDP). This could be due to the increase in the population in high density planting. This was in accordance with the study conducted by Randhawa *et al.*, (1973), under Bangalore condition in 'Robusta' banana. Higher levels of nutrient application had a significant influence on plant height and girth. Especially, the application of phosphorus along with nitrogen and potassium help in the formation of complex nitrogenous substances such as protein and amino acids that are the building blocks of tissues. This was in conformation with earlier reports that the higher levels of phosphorus, nitrogen and potassium increase plant height and girth (Thippesha, 2004; Apshara and Sathiyamoorthy, 1997). Among the placements, application of fertilizers at a distance between 35 and 55 cm had resulted in higher plant height and girth. This could be attributed to the presence of more number of active roots in that placement which effectively utilize applied fertilizers compared to closer and wider distance.

### **Number of functional and total leaves**

Leaves are the primary sites for photosynthesis; hence, they are very closely related to the growth and productivity of any crop. In banana, the number of functional and total leaves is very closely related to one another and together they determine the growth and productivity. In the present investigation, number of functional and total leaves recorded at shooting stage differed significantly among the treatments (Table 1). Maximum production of functional leaves was observed with 100 per cent recommended dose of phosphorus (16.3), followed by 80 per cent recommended phosphorus (16.0), while 60 per cent of RDP produced lesser number of

functional leaves (13.0). Similar trend was also followed in total number of leaves. The plants under high-density planting system produced more number of leaves and functional leaves to overcome competition. This can be further explained by the fact that the plants in closer spacing took more time to reach shooting stage. Total number of leaves produced and the rate of leaf production are influenced by mineral nutrition. The treatments with higher level of nutrients resulted in more number of total leaves and functional leaves. The higher levels of phosphorus, nitrogen and potassium promote faster rate of leaf production resulting in increased leaf area and leaf area index. Studies carried out by Turner and Barkus (1982), Stover (1984), Apshara (1997), Kumar and Nalina (2001) and Thippesha, (2004) were also of the same opinion. Among different placement, the application of fertilizer in middle placement (35-55cm) increased the total number of leaves and functional leaves compared to the other treatments. This might be due to the presence of more number of active roots in that zone. Presence of more number of active roots was influenced in the uptake of nutrients by the banana plant (Kurien *et al.*, 2006). In another study, it was reported that during early stages of banana (8<sup>th</sup> and 16<sup>th</sup> leaf stage) fertilizer may be applied in 25 cm circular bands between 25 and 50 cm radial distances whereas, during the later stages, in wider bands of 50 cm width between 25 and 75 cm radial distances (Keshava Murthy and Kotur, 1998).

### **Number of days taken for flowering, shooting and harvesting**

Crop duration can be divided into two phases. The first phase is the days taken from planting to shooting (vegetative stage) and the second phase is the days taken from shooting to harvesting (reproductive phase). The data given in Table 2 revealed that the number of

days taken for 50 per cent flowering, shooting, shooting to harvesting and planting to harvesting differed significantly among the treatments. These durations were prominently increased with increasing plant population. Comparing different treatments, number of days taken for 50 per cent flowering ranged from 295 days in 100% RDP to 337 days in 60% RDP. The data further revealed that the application of fertilizer at the band width of 20 cm between 35-55 cm from pseudostem produced 50 per cent flowering relatively earlier compared to closer (15-35 cm) and wider band width (55-75 cm). The effect of high density planting, doses and placement of fertilizer in the present investigation showed a pronounced extension of duration. In almost all the experiments conducted both in India and other banana growing countries in the world, many workers had reported extended crop duration under high density planting. All the treatments, where the plants received higher dosage of nutrients recorded early flowering, shooting and harvesting compared to application of 80 and 60 per cent of recommended dose of fertilizers (Thippesha, 2004). Singh *et al.*, (1977) observed that the highest level of N, P and K caused early emergence of inflorescence. Early flowering with higher amount of nutrients may be due to improvement in leaf size and thereby net assimilation rate, presumably lead to early maturity of plant, which might have resulted in early initiation and emergence of inflorescence (Hasan *et al.*, 2001).

Number of days taken for shooting from planting (Table 4) increased with application of fertilizer at closer band width (15-35 cm) and wider band width (55-75 cm). However, the application of fertilizers at the middle distance (35-55 cm) reduced the number of days taken for shooting from planting. Among the treatments, the 100% RDP at 35-55 cm placement recorded minimum number of days (302 days) taken for shooting from planting

than other treatments and, 80% RDP at 35-55 cm placement (312.7 days) was found to be on par with 100% RDP (302 days). Maximum number of days (349.2 days) taken for shooting was with 60% RDP at 55-75 cm placement. Similar trend was also followed in days to harvesting from planting and days to harvesting from shooting. Delayed shooting and harvesting in high density planting might be attributed to two reasons. The limited assimilates supplied to shoot in high density planting (closer spacing) by the reduced photosynthetic efficiency of individual leaves due to mutual shading and the slow rate of bunch growth in closer plantings due to the low temperature. Alagiamanavalan and Balakrishnan (1976) attributed the extended duration under high density planting to the competition between two adjacent plants for light. The increased length of vegetative cycle under HDP should be compensated by higher yields per unit area as mentioned by Thippesha (2004), so that, the farmers can afford to wait for extra period.

### **Dry matter production**

The accumulation and distribution of biomass in various parts of the plant plays a vital role in determining the growth and production in banana. The total dry matter production (DMP) at shooting significantly not differed with different levels and placement of fertilizers (Table 3). In general, an increased trend in dry matter production was observed due to increased level of nutrients application at proper placement. The plant supplied with full dose of recommended dose of fertilizer at 35-55 cm distance recorded the maximum dry matter production per plant (7.31 kg) and per hectare (32.49 t/ha), while the minimum dry matter production per plant (6.44 kg) and per hectare (28.62 t/ha) was recorded with application of 60 per cent of recommended dose of fertilizers at wider placement of 55-75 cm. Higher accumulation of dry matter in the

treatments supplied with 100 per cent recommended dose of fertilizers at middle placement indicated that there was better uptake and translocation of nutrients. Higher dry matter production in these treatments might be due to better plant growth, more number of leaves per plant, more leaf area per plant and better uptake of nutrients from the soil. These findings confirmed the reports of Turner and Barkus (1981) and Thippesha (2004). The exposure of the root system to zones with high P concentrations due to fertilizer placement at 35-55 cm distance resulted in higher dry matter production. Similar kind of findings was reported by Hansel *et al.*, (2017) in soybean.

### **Phosphorus derived from fertilizer (pdff)**

Phosphorus derived from fertilizer is a robust measure of the recovery of the tracer. The data on Pdff at 20 days interval, up to 80 days as influenced by different levels and placement of phosphorus fertilizers are given in the Table 4. The per cent Pdff was found to be significantly affected by different levels and placement of phosphorus fertilizers. Pdff increased significantly and progressively as the phosphorus dose increased from 60 to 100% of recommended dose. Application of 100 per cent recommended dose of fertilizer at closer placement of 15 to 35 cm gave highest per cent Pdff (11.4) than other treatments at early vegetative stage. At late vegetative stage, the Pdff (16.0) was highest with application of same dose of fertilizer at middle placement (35-55 cm). However, the lowest per cent pdff (7.84) was recorded with application 60 per cent recommended phosphorus at wider placement (55-75 cm). The <sup>32</sup>P recovery was decreased with increasing P application distance from the pseudo stem of the plant. It was possibly because the P diffusion coefficient was much smaller in soil and P absorption by the plant depended mainly on root contact with P fertilizer (Zhou *et al.*,

2009). Per cent Pdff was steeper when fertilizer P was applied at the early vegetative and late vegetative stages as compared to application at bud differentiation stage. This indicates quicker absorption of fertilizer P during early stages of growth as the early stage of growth in banana is critical for subsequent development (Kurien *et al.*, 2006; Keshava Murthy and Iyengar, 1994). It might also be due to higher rate of absorption of applied P fertilizers and P requirement in vegetative stage. On the other hand, during bud differentiation stage, the P requirement of the new shoot growth might be largely met by internal mobilization of P stored within the plant resulting in a lower Pdff at this growth stage.

At early vegetative stage, placement of full dose of recommended phosphorus between 15 and 35 cm resulted in the highest Pdff which was significantly higher than all other treatments. However, the higher Pdff was recorded with the placement of full dose of recommended dose of fertilizers between 35 and 55 cm at late vegetative stage and bud differentiation stage. This was due to efficient placement of fertilizers within the shoot canopy and also due to the presence of more number of active roots within this zone (Keshava Murthy and Iyengar, 1990 and Keshava Murthy and Iyengar, 1994). Low Pdff in bud differentiation stage compared to vegetative stages might be due to dilution of the labelled P within the plant. An experimental constraint in assessing the Pdff over long periods was the detectable limits of the instruments to count <sup>32</sup>P activity due to its relatively short half life (Keshava Murthy and Kotur, 1998; Kalaivanan *et al.*, 2014). Among sampling intervals, there was a progressive increase in Pdff due to increased absorption of phosphorus with time. Therefore, the highest Pdff was observed at 80 days after application of the fertilizer in all the applications.

**Phosphorus content, P uptake, fertilizer P uptake and fertilizer utilization**

Banana requires high amount of mineral nutrients for its growth and production. Rapidly differentiating tissues in banana throughout the life cycle are associated with high concentration of nutrients. Therefore, large changes in concentration and uptake of nutrients take place in the plant from planting to fruit development. In any nutrient management study, uptake of nutrients should reflect on yield, so as to claim the favourable effect on nutrient use efficiency, which was well pronounced in the current investigation. The data pertaining to P content in entire plant, total P uptake, fertilizer P uptake and per cent fertilizer utilization with different levels and placement of labelled <sup>32</sup>P fertilizers are given in the Table 3 and 5. Data on total P concentration in the entire plant of banana cv. Robusta collected at different time intervals after fertilizer P application differed significantly with different levels and placement of labelled <sup>32</sup>P single super phosphate even though the slight variation was found in the concentration of phosphorus

between the treatments. Highest total P (16.0 g plant<sup>-1</sup> and 71.13 kg ha<sup>-1</sup>) and fertilizer P uptake (1.96 g plant<sup>-1</sup> and 8.72 kg ha<sup>-1</sup>) was recorded with application of full dose of recommended phosphorus. The lowest amount of total (13.24 g plant<sup>-1</sup> and 58.86 kg ha<sup>-1</sup>) and fertilizer P uptake (1.08 g plant<sup>-1</sup> and 4.80 kg ha<sup>-1</sup>) was recorded with 60% recommended phosphorus. Higher uptake of nutrients might be due to higher availability of P for individual plants. Band placement of P fertilizer can contribute to increase P availability to the root system by reducing potential P fixation in soils (Shen *et al.*, 2011). Extensive root distribution promoted by band placement of P fertilizer may contribute to increase P use efficiency (Hansel *et al.*, 2017). The uptake of P was observed to be positively correlated to plant height, pseudostem girth, number of leaves and Pdf. The results were in confirmation with the findings of Thippesha (2004). With reference to the per cent fertilizer utilization, the maximum fertilizer utilization was registered with 60% recommended phosphorus, followed by 80 and 100% of recommended phosphorus.

**Table.1** Effect of different doses and placements of labelled SSP on vegetative growth parameters at shooting stage in banana cv. Robusta

Doses of Phosphorus (%)	Placement of the fertilizer between(cm)	Plant height (cm)	Pseudostem girth (cm)	No. of functional leaves	Total number of leaves
60	15-35	205.80 <sup>ABC</sup>	56.73 <sup>D</sup>	14.00 <sup>CD</sup>	27.30 <sup>ABCD</sup>
	35-55	207.53 <sup>AB</sup>	58.47 <sup>C</sup>	14.30 <sup>BCD</sup>	27.70 <sup>ABC</sup>
	55-75	196.67 <sup>C</sup>	54.33 <sup>E</sup>	13.00 <sup>D</sup>	24.70 <sup>D</sup>
80	15-35	210.30 <sup>A</sup>	61.87 <sup>B</sup>	14.70 <sup>ABCD</sup>	28.30 <sup>AB</sup>
	35-55	211.23 <sup>A</sup>	62.33 <sup>B</sup>	16.00 <sup>AB</sup>	29.00 <sup>AB</sup>
	55-75	198.43 <sup>BC</sup>	54.50 <sup>E</sup>	13.30 <sup>CD</sup>	25.30 <sup>CD</sup>
100	15-35	210.80 <sup>A</sup>	62.10 <sup>B</sup>	15.00 <sup>ABC</sup>	28.30 <sup>AB</sup>
	35-55	212.40 <sup>A</sup>	63.40 <sup>A</sup>	16.30 <sup>A</sup>	29.70 <sup>A</sup>
	55-75	205.50 <sup>ABC</sup>	56.20 <sup>D</sup>	13.70 <sup>CD</sup>	26.30 <sup>BCD</sup>
SE(d)		4.329	0.452	0.935	1.285
LSD @ 5%		9.1774	0.9589	1.9825	2.7245

Means with at least one letter common are not statistically significant using Fisher's Least Significant Difference



**Table.2** Effect of different levels and placement of labelled SSP on number of days taken for 50 per cent flowering, shooting from planting, harvesting from shooting and harvesting of banana cv. Robusta

Doses of Phosphorus (%)	Placement of the fertilizer between(cm)	Days to 50 per cent flowering	Days to shooting from planting	Days to harvesting	Days to harvesting from shooting
60	15-35	318.00 <sup>BC</sup>	332.00 <sup>ABCD</sup>	474.70 <sup>BC</sup>	142.70 <sup>ABC</sup>
	35-55	316.00 <sup>BCD</sup>	327.80 <sup>BCDE</sup>	467.30 <sup>BCD</sup>	139.50 <sup>ABCD</sup>
	55-75	337.00 <sup>A</sup>	349.20 <sup>A</sup>	500.30 <sup>A</sup>	151.10 <sup>A</sup>
80	15-35	309.00 <sup>CDE</sup>	321.50 <sup>CDEF</sup>	455.80 <sup>CDE</sup>	134.30 <sup>BCD</sup>
	35-55	302.00 <sup>DE</sup>	312.70 <sup>EF</sup>	441.10 <sup>EF</sup>	128.40 <sup>D</sup>
	55-75	330.00 <sup>AB</sup>	342.70 <sup>AB</sup>	489.20 <sup>AB</sup>	146.50 <sup>AB</sup>
100	15-35	312.67 <sup>CD</sup>	314.57 <sup>DEF</sup>	449.20 <sup>DEF</sup>	134.63 <sup>BCD</sup>
	35-55	295.00 <sup>E</sup>	302.00 <sup>F</sup>	431.27 <sup>F</sup>	129.27 <sup>CD</sup>
	55-75	324.00 <sup>ABC</sup>	336.00 <sup>ABC</sup>	472.63 <sup>BC</sup>	136.63 <sup>BCD</sup>
SE(d)		7.155	8.027	10.371	5.949
LSD @ 5%		15.168	17.017	21.986	12.611

Means with atleast one letter common are not statistically significant using Fisher's Least Significant Difference

**Table.3** Dry matter production, P content in entire plant and total P uptake of ‘Robusta’ banana as influenced by different doses and placement of labelled single super phosphate

Doses of Phosphorus (%)	Placement of the fertilizer between(cm)	Dry matter production (kg/plant)	Dry matter production (t/ha)	P (%)	Total P uptake (g/plant)	Total P uptake (kg/ha)
60	15-35	6.79	30.17	0.21 <sup>BCD</sup>	14.45	64.18 <sup>ABCD</sup>
	35-55	6.86	30.49	0.21 <sup>DE</sup>	14.23	63.22 <sup>BCD</sup>
	55-75	6.44	28.62	0.21 <sup>E</sup>	13.24	58.86 <sup>D</sup>
80	15-35	6.92	30.75	0.22 <sup>ABC</sup>	15.04	66.83 <sup>ABC</sup>
	35-55	7.24	32.17	0.22 <sup>ABC</sup>	15.68	69.70 <sup>AB</sup>
	55-75	6.61	29.37	0.21 <sup>DE</sup>	13.86	61.67 <sup>CD</sup>
100	15-35	7.29	32.40	0.22 <sup>AB</sup>	15.88	70.61 <sup>A</sup>
	35-55	7.31	32.49	0.22 <sup>A</sup>	16.00	71.13 <sup>A</sup>
	55-75	6.64	29.51	0.21 <sup>CD</sup>	14.14	62.69 <sup>BCD</sup>
SE(d)		0.846	1.766	0.003	2.321	3.354
LSD @ 5%		NS	NS	0.0054	NS	7.1099

Means with atleast one letter common are not statistically significant using Fisher's Least Significant Difference

**Table.4** Effect of different doses and placement of labelled SSP on Pdf (%) of banana cv. Robusta at different time intervals after fertilizer P application at three growth stages

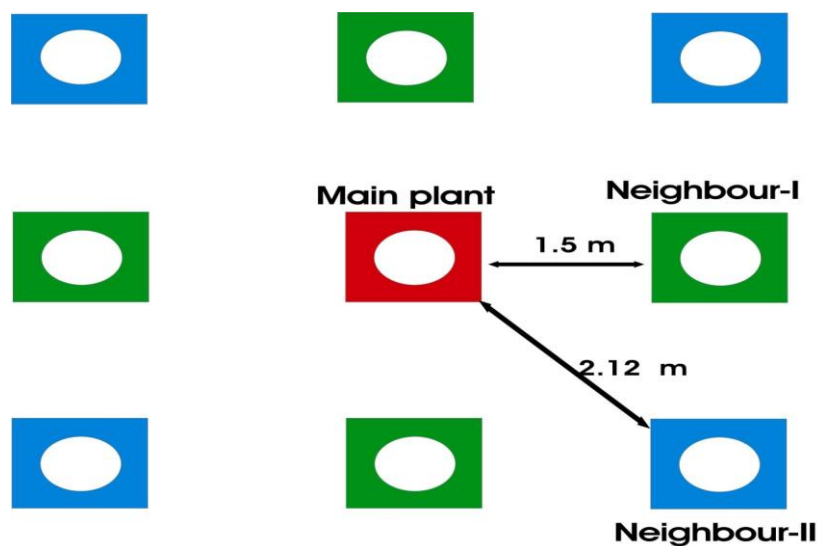
Doses of Phosphorus (%)	Placement of the fertilizer between(cm)	Early vegetative stage				Late vegetative stage				Bud differentiation stage			
		Days after fertilizer application				Days after fertilizer application				Days after fertilizer application			
		20 <sup>th</sup>	40 <sup>th</sup>	60 <sup>th</sup>	80 <sup>th</sup>	20 <sup>th</sup>	40 <sup>th</sup>	60 <sup>th</sup>	80 <sup>th</sup>	20 <sup>th</sup>	40 <sup>th</sup>	60 <sup>th</sup>	80 <sup>th</sup>
<b>60</b>	<b>15-35</b>	0.10	0.90	1.96	8.77	0.11	1.14	2.41	10.6	0.12	1.11	2.16	9.88
	<b>35-55</b>	0.09	0.89	1.83	8.63	0.14	1.20	2.46	10.3	0.13	1.09	2.31	10.1
	<b>55-75</b>	0.07	0.76	1.57	7.84	0.08	0.96	1.80	8.72	0.08	0.73	1.73	7.93
<b>80</b>	<b>15-35</b>	0.22	1.50	2.80	10.3	0.24	1.63	3.92	11.4	0.22	1.12	2.84	10.5
	<b>35-55</b>	0.18	0.97	2.33	9.47	0.30	2.27	6.27	13.0	0.27	1.27	3.54	10.7
	<b>55-75</b>	0.07	0.87	1.55	8.55	0.09	1.06	2.12	9.71	0.09	0.90	1.83	7.90
<b>100</b>	<b>15-35</b>	0.27	2.08	3.44	11.4	0.26	1.86	4.12	11.5	0.25	1.15	3.35	10.6
	<b>35-55</b>	0.20	1.40	2.45	9.79	0.31	2.47	6.56	16.0	0.26	1.37	4.06	11.0
	<b>55-75</b>	0.08	0.87	1.56	8.72	0.11	1.11	2.29	10.4	0.10	0.95	1.92	8.60
<b>SE(d)</b>		0.01	0.07	0.09	0.65	0.01	0.07	0.22	0.75	0.01	0.06	0.21	0.75
<b>LSD @ 5%</b>		0.02	0.20	0.28	1.95	0.03	0.22	0.65	2.24	0.03	0.19	0.64	2.24

**Table.5** Pdf, fertilizer P utilization and yield of Robusta banana as influenced by different doses and placement of labeled SSP

Doses of Phosphorus (%)	Placement of the fertilizer between(cm)	Pdff (%)	Fertilizer P uptake (g/plant)	Fertilizer P uptake (kg/ha)	Fertilizer P utilization (%)	Bunch weight (kg/plant)	Bunch yield (t/ha)
60	15-35	9.75 <sup>BCD</sup>	1.41 <sup>CD</sup>	6.26 <sup>CD</sup>	6.71 <sup>A</sup>	19.77 <sup>D</sup>	87.84 <sup>D</sup>
	35-55	9.68 <sup>BCD</sup>	1.38 <sup>CD</sup>	6.12 <sup>CD</sup>	6.56 <sup>AB</sup>	20.33 <sup>CD</sup>	90.36 <sup>CD</sup>
	55-75	8.16 <sup>D</sup>	1.08 <sup>E</sup>	4.80 <sup>E</sup>	5.15 <sup>DE</sup>	17.23 <sup>F</sup>	76.58 <sup>F</sup>
80	15-35	10.73 <sup>ABC</sup>	1.61 <sup>BC</sup>	7.17 <sup>BC</sup>	5.77 <sup>BCD</sup>	20.73 <sup>C</sup>	92.14 <sup>C</sup>
	35-55	11.06 <sup>AB</sup>	1.73 <sup>AB</sup>	7.71 <sup>AB</sup>	6.19 <sup>ABC</sup>	21.77 <sup>AB</sup>	96.73 <sup>AB</sup>
	55-75	8.72 <sup>D</sup>	1.21 <sup>DE</sup>	5.38 <sup>DE</sup>	4.32 <sup>EF</sup>	18.30 <sup>E</sup>	81.33 <sup>E</sup>
100	15-35	11.17 <sup>AB</sup>	1.77 <sup>AB</sup>	7.88 <sup>AB</sup>	5.07 <sup>DE</sup>	21.07 <sup>BC</sup>	93.62 <sup>BC</sup>
	35-55	12.26 <sup>A</sup>	1.96 <sup>A</sup>	8.72 <sup>A</sup>	5.61 <sup>CD</sup>	22.17 <sup>A</sup>	98.51 <sup>A</sup>
	55-75	9.24 <sup>CD</sup>	1.31 <sup>DE</sup>	5.79 <sup>DE</sup>	3.73 <sup>F</sup>	18.87 <sup>E</sup>	83.84 <sup>E</sup>
SE(d)		0.826	0.133	0.591	0.395	0.380	1.690
LSD @ 5%		1.7511	0.2816	1.2521	0.837	0.8064	3.5835

Means with atleast one letter common are not statistically significant using Fisher's Least Significant Difference

**Fig.1** Single experimental plot



The higher utilization of P at lower level of P application was mainly due to greater competition among the plants for limited nutrient. Hence, further elaboration and discussion on the aspect is restricted (Walmsley and Twyford, 1968).

**Bunch weight and bunch yield**

The highest bunch weight (22.17 kg) and yield (98.51 t ha<sup>-1</sup>) was obtained when phosphorus applied at 100% dose between 35 and 55 cm distances, closely followed by 80%

dose applied between 35 and 55 cm. The findings show that the latter treatment enables 20% saving in fertilizer phosphorus input without significant reduction in fruit yield. Interestingly, computation of the marketable yield from bunch weight showed a tremendous increase in yield per unit area with increasing plant population under high density planting (Chaudhuri and Baruah, 2010). Among the placements, the application of fertilizers between 35 and 55 cm distances yielded highest bunch weight and yield which were closely followed by application between 15 and 35cm distances. Similar kind of results was also reported by Kotur (2012). Application of fertilizer at the farthest distance between 55 and 75 cm was distinctly inferior showing that there was little scope of application of fertilizers between the rows under the high density planting of banana and it is best to apply fertilizer in a circular strips between 15 and 55 cm distances at 5 cm depth.

From the results on growth, Pdf, fertilizer P uptake and bunch yield, it can be concluded that the split application of 100% recommended dose of P at the distance of 15-35 cm from pseudo stem during early vegetative stage and at 35-55 cm distance during late vegetative and bud differentiation stage under high density planting are beneficial to banana for getting good yield. However, the application of 80 per cent dose of recommended P fertilizer also at par with above treatment. Considering the economy, application of 80 per cent of recommended dose of P fertilizer in a circular strip between 15 and 55 cm from pseudostem can be more profitable than full dose of P fertilizer to banana cv. Robusta.

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