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RESEARCH ARTICLE

EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON CORM AND ROOT GROWTH AND PHYSIOLOGICAL PARAMETERS OF BANANA

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Abstract

Field investigations were carried out at Northern Block farm, Agricultural Research Station (Tamil Nadu Agricultural University), Bhavanisagar, Erode district of Tamil Nadu during 2010-11 and 2011-12 to study the effect of integrated nutrient management practices on productivity of banana under irrigated conditions. The experiments consisted of thirteen treatments *viz.*, Control (100% recommended dose of fertilizer), four treatments consisted of *Wellgro soil* @ 20 and 40% in combination with 100 and 75% RDF, two treatments consisted of 2% liquid organic manure spray along with 100 and 75% RDF, four treatments consisted of *Wellgro grains* @ 20 and 40% combined with 100 and 75% RDF and the last two treatments comprised of FYM @ 10kg plant^{-1} with 100 and 75% RDF. The banana *cv*. Grand Naine (AAA) was used as a test crop in both the years of study. The experiments were laid out in Randomized Complete Block Design with three replications. The results revealed that application of 100% RDF along with 40% *Wellgro soil* registered significantly higher root number (242.57 and 233.00), corm circumference (79.17 and 79.17cm) and corm volume (4.10 and 4.73 litre plant^{-1}) during 2010-11 and 2011-12, respectively. Similarly the growth analysis parameters such as leaf area index, crop growth rate, relative growth rate, net assimilation rate and absolute growth rate and physiological parameters (total chlorophyll, soluble protein and nitrate reductase activity) showed significant improvement on 100% RDF along with either 40% *Wellgro soil* or FYM 10kg plant^{-1} during both the years of experimentation. Hence, integrated nutrient management practices have been found to be an ideal option to improve growth and physiological parameters of banana under soil and climatic conditions of Western zone of Tamil Nadu.

Introduction

Banana (*Musa* sp.) is the fifth largest agricultural commodity in the world trade after cereals, sugar, coffee and cocoa and the second largest fruit crop in the world. Banana is a cheap source of energy like vitamins A, C, B_6 and other minerals with traces of fat. At present, banana production in India is 27.0 million tonnes from an area of 0.77 million ha and the productivity is 34.4 tonnes. The major banana growing states in India are Tamil Nadu, Maharashtra, Gujarat, Andhra Pradesh, Karnataka, Madhya Pradesh, Bihar and West Bengal. Tamil Nadu has the largest area of 0.12 million ha and the production is 6.4 million tonnes while Maharashtra has the second largest area of 0.08 million ha with a production of 5.2 million tonnes (Anon., 2010).

Banana owing to its large size and rapid growth rate require relatively large amount of nutrients for high yields of quality fruits and it is estimated that 50 tonnes of banana in one hectare removes 320kg N, 32kg P_2O_5 and 925kg

K_2O every year (Lahav and Turner, 1983). Application of inorganic fertilizers though increases the yield substantially but could not able to sustain the fertility status of the soil (Bharadwaj and Omanwar, 1994) and have caused several undesirable consequences in the fragile soil eco-system, leading to gradual decline in productivity. Considering the present situation of soil quality and environmental security, it is necessary to go for an integrated nutrient management, involving various sources of organic manures, organic cakes and bio-fertilizers besides using chemical fertilizers in banana. Integrated nutrient management in banana are being practiced and experimented in various parts of our country. Bhalerao et al. (2009) observed that combined application of 100% recommended dose of NPK along with organic manures increased the growth and also yield attributes. Similar trend was also reported by Hazarika and Ansari (2010a); Badgujar et al. (2010) and Barakat et al. (2011) in banana.

In today's cultivation many commercial organic manures are being used because of their application in lesser volume and also enriched with nutrients. One such commercial organic manure used in the study was *Wellgro*. *Wellgro* organic manure is a unique product with a blend of neem and non-timber forest produce and a rich source of nutrients and this organic based farm input addresses soil fertility and crop nutrition in line with the perception of Integrated Nutrient Management (INM). Reddy (2005a) found that application of *Wellgro soil* along with 100% RDF recorded the maximum yield in rice. Similar line of results was also obtained by Reddy (2005b) in cotton, Senthurpandiyan (2007) in tea, Srivastava (2008) in potato and Prabhakar and Hebbar (2008) in tomato.

The research on effect of integrated nutrient management practices on banana with commercial formulations of organic products (*Wellgro*) is new under the soil and climatic conditions of Western zone of Tamil Nadu. Hence, this study was under taken to find out the influence of INM on growth and physiological parameters of banana.

Material and Methods

The experiments were laid out at Northern Block Farm, Agricultural Research Station (Tamil Nadu Agricultural University), Bhavanisagar, Erode district of Tamil Nadu. The farm is geographically located at 11°29′ N latitude and 77°08′ E longitude at an altitude of 256 m above MSL.

The experiments were conducted under irrigated conditions. Throughout the experiment, the mean annual rainfall was 538.8 mm in 38 rainy days and 742.8 in 43 rainy days during first and second year, respectively. The mean maximum and minimum temperatures recorded were 33.8°C and 21.9°C in 2010-11 and 34°C and 21.1°C in 2011-12. Similarly, the mean maximum and minimum relative humidity was 87.8 and 50.2% during 2010-11 and 86.2 and 56.3% during 2011-12. Mean bright sunshine hours per day was 4.67 with a mean solar radiation of 453 cal cm^2 day^{-1}. The soil type was sandy loam in texture. The soils were neutral (pH 7.06 and 7.18) with low soluble salts (EC 0.263 and 0.254 dSm^{-1}), medium and low in organic carbon content (0.51 and 0.46%), low in available nitrogen (208 and 232 kg/ha), medium in available phosphorus (14.7 and 15.3 kg/ha) and high in available potassium (611 and 649 kg/ha) for 2010-11 and 2011-12, respectively. Similarly, soil bulk density was 1.35 and 1.28 g/cc, particle density was 2.27 and 2.31g/cc and porosity was 40.3 and 44.6% during 2010-11 and 2011-12, respectively.

The banana *cv.* Grand Naine (AAA) was used as a test crop during both the years of experimentation. The field was uniformly levelled and the pits were dug out to a dimension of 45x45x30 cm at 1.8m×1.8m spacing and plot size was 14.4m x 5.4m (77.76 m^2). The experiment was laid out in a Randomized Complete Block Design with thirteen treatments and replicated thrice as suggested by Gomez and Gomez (2010). The treatment comprises T_1- 100% recommended dose of fertilizer (control), T_2- 100% RDF + *Wellgro soil* @ 20% w/w of chemical fertilizers, T_3- 100% RDF + *Wellgro soil* @ 40% w/w of chemical fertilizers, T_4- 75% RDF + *Wellgro soil* @ 20% w/w of chemical fertilizers, T_5- 75% RDF + *Wellgro soil* @ 40% w/w of chemical fertilizers,T_6- 100% RDF + 2% liquid organic manure spray (LOM) on bunches, T_7- 75% RDF + 2% liquid organic manure spray (LOM) on bunches, T_8- 100% RDF + *Wellgro grains* @ 20% w/w of chemical fertilizers, T_9- 100% RDF + *Wellgro grains* @ 40% w/w of chemical fertilizers, T_{10}- 75% RDF + *Wellgro grains* @ 20% w/w of chemical fertilizers, T_{11}- 75% RDF + *Wellgro grains* @ 40% w/w of chemical fertilizers, T_{12}- 100% RDF + FYM @ 10kg/plant and T_{13}- 75% RDF + FYM @ 10kg/plant.

The following formula was used to calculate the quantity of *Wellgro soil* and *Wellgro grains* @ 20 and 40% w/w of chemical fertilizers.

$$\textit{Wellgro soil/grains}\ (\text{g plant}^{-1}\ \text{split}^{-1}) = \frac{\text{Urea+ super phosphate+ muriate of potash (g plant}^{-1}\ \text{split}^{-1})}{100} \times 20 \text{ or } 40\%$$

The experimental plots consisted of three rows with eight plants in each row. The plots were separated by buffer channels to minimize the movement of nutrients and water. At the time of planting, Furadon granules were applied @ 20g/pit. Applied *Azospirillum* and *Phosphobacteria* 20g each and Vasicular Arbuscular Mycorrhizae (VAM) @ 10kg/ha at planting and 5th month after planting uniformly to all the treatments.

The 100 and 75% recommended dose of fertilizers *i.e*., 165-52.5-495 and 123.7-39.4-371.3g N-P-K/plant respectively were applied through urea, single super phosphate (SSP) and muriate of potash (MOP). Entire dose of phosphorus and FYM were applied during 2nd month after planting to scheduled treatments. Remaining nitrogen and potash were applied along with *Wellgro* organic manures at 2nd, 4th, 6th and 8th MAP (two months interval). Fertilizers and organic manures were applied in a circular band around the base of the plants. Liquid organic manure @ 2% was sprayed twice (*i.e*., at 15 and 30 days after last hand opening) uniformly on the foliage and developing bunches. Other cultural practices like weeding, irrigation, pest and disease management and special operations like desuckering, denavelling, pruning of leaves, earthing up and propping were followed uniformly for raising the crop as per the Crop Production Techniques of Horticultural crops (2004).

Observations on corm and root characteristics at shooting stage

At shooting stage, corm was separated from the plant and roots were counted and average was expressed in numbers. Roots were separated from corm and washed with water. The root and corm volume was measured by water displacement method and expressed in litre plant^{-1} (Anon, 2011). Similarly, corm circumference was determined by measuring individual corm with a tape at the widest midpoint and expressed in cm.

Physiological parameters

Soluble protein content of leaf was estimated at 660 nm by using Folin Ciocalteau reagent by following the procedure described by Lowry et al. (1951) and expressed in mg g^{-1} of fresh weight. Nitrate reductase activity was also estimated at 540 nm by using naphthalene ethylene diamine dihydrochloride by following the method described by Nicholas et al. (1976) and expressed as µ moles NO_2 g^{-1}hr^{-1} of fresh weight. Chlorophyll *a* and *b* and total chlorophyll was estimated by adopting the procedure of Yoshida et al. (1971) and expressed as mg g^{-1} of fresh weight.

Growth analysis

Leaf area index (LAI) was calculated by using the formula proposed by Watson (1952). CGR was arrived at using the formula suggested by Watson (1958) and expressed in gm^{-2} day^{-1}. The RGR was determined by adopting the formula suggested by Williams (1946) and expressed in mg g^{-1}day^{-1}. The method proposed by Gregory (1918) and modified by Williams (1946) was employed for calculating NAR and it was calculated on leaf dry weight basis and the values expressed in mg g^{-1}day^{-1}. The AGR was calculated by adopting the formula suggested by Kvet et al. (1971) and expressed in g plant^{-1}day^{-1}.

Results

Root characteristics

During 2010-11, the highest root number was noted in the treatment 100% RDF + 40% *Wellgro soil* (242.57). However, it was statistically on par with T_{12}. During 2011-12, banana root numbers were its maximum (236.33) due to application of 100% RDF + FYM @ 10kg plant^{-1} (T_{12}) which was comparable to T_3, T_9, T_2 and T_{13}. However, the lowest root number was recorded under T_7 (75% RDF + liquid organic manure spray on bunches) during both the years of experimentation (Table 1). This indicates that the banana is able to produce more roots in the presence of adequate nutrients combined with organic manures, resulting in better morphological and other economic traits. Application of inorganic fertilizers along with FYM, *Wellgro soil* and *Wellgro grains* had significant impact on root volume during both the years of study.

However, combined application of 100% RDF + FYM @ 10kg plant^{-1} (T_{12}) registered the maximum root volume during 2010-11 (1.65 litre plant^{-1}) but, it was statistically on par with T_3 and T_9. Similarly, the same treatment recorded the maximum root volume during 2011-12 also (1.59 litre plant^{-1}). However, it was statistically on par with T_3, T_2 and T_9 at shooting stage of banana. The lowest root volume was recorded in T_7 during both the years of experimentation.

Corm characteristics

The corm circumference and volume recorded at various stages in both the years revealed that application of 100% RDF along with either FYM @ 10kg plant^{-1} or 40% *Wellgro soil* were effective in increasing the above traits (Table 1). During the study, corm circumference was highest at shooting stage of banana. The INM practices considerably influenced corm circumference and volume in banana during both the years of study. The maximum corm circumference (79.17cm) was observed with 100% recommended dose of fertilizer along with 40% *Wellgro soil* (T_3) at shooting stage of growth during both the years of study. Whereas, the treatments T_{12}, T_2, T_{13}, T_8 and T_9 were on par with T_3 during 2010-11 and it was T_{12}, T_2, T_9, T_{13} and T_8 during 2011-12. Similarly, treatment T_3 recorded the maximum corm volume (4.10 and 4.73 litre plant^{-1}) during 2010-11 and 2011-12. It was comparable with T_{12} and T_2 during 2010-11 and T_{12}, T_9, T_2, T_5, T_8 and T_{11} during 2011-12.

Growth analysis

Leaf area index (LAI) is an important source in manufacturing photoassimilates for determining dry matter accumulation and crop yield. An increase in LAI results in better utilization of solar energy. Thus, leading to higher dry matter accumulation through the process of photosynthesis. It is a positive index with direct influence on plant growth. Similar response was observed in the present study due to various integrated nutrient management treatments (Table 2). At the time of shooting, the treatment 100% recommended dose of fertilizer along with FYM @ 10kg plant^{-1} (5.65) recorded the maximum leaf area index which was on par with T_2 and T_3 during 2010-11and the lowest LAI was observed in T_7. During 2011-12, application of 100% RDF along with 40% *Wellgro soil* registered the maximum LAI (5.87) it was on par with T_{12} and T_2. The lowest LAI was observed in control plot (T_7) at shooting stage of banana. Growth analysis is necessary to understand the plant growth in quantitative terms and to interpret crop yields under different environments. In the present investigation, growth analysis was worked out at 5 MAP- shooting stage (Table 2). The result revealed that the treatment of 100% RDF along with either 40% *Wellgro soil* or FYM @ 10kg plant^{-1} recorded the maximum CGR, RGR, NAR and AGR. These parameters being measures of assimilates of photosynthesis in the leaf. Crop growth rate was found to be influenced significantly by different INM treatments in both the years. Application of 100% RDF along with 40% *Wellgro soil* registered highest CGR at 5 MAP-shooting (15.23 and 13.22 g m^{-2} day^{-1}) during the year 2010-11 and 2011-12, respectively and it was on par with T_{12}. During 2010-11, the lowest CGR was recorded in T_7 and T_4 during 2011-12.

Relative growth rate was found to be un-affected due to adoption of different INM treatments. Combined application of 100% RDF either with 40% *Wellgro soil* or FYM @ 10kg plant^{-1} recorded the highest rate of absolute growth rate. However, 100% RDF + 40% *Wellgro soil* recorded the maximum AGR at 5 MAP-shooting (49.34 and 42.82 g plant^{-1}) during 2010-11 and 2011-12 respectively and it was on par with T_{12} during both the years of study. The lowest absolute growth rate was recorded with T_7 during 2010-11 and with T_4 during 2011-12. The net assimilation rate showed variations due to INM treatments in both the years of study except at 5 MAP- shooting stages during 2011-12. Where, application of 100% RDF along with FYM @ 10kg plant^{-1} (31.64 mg g^{-1} day^{-1}) recorded the maximum NAR at 5 MAP- shooting during 2010-11 but it was on par with T_{13} (Table 2).

Physiological parameters

In the current study, the chlorophyll *a*, *b* and total chlorophyll content estimated at various stages from 3 MAP to harvest stage, indicated that application of 100% RDF either with 40% *Wellgro soil* or FYM @ 10kg plant resulted in higher chlorophyll content (Table 3). These treatments are more efficient in maintaining a better photosynthetic efficiency, which is responsible to maintain a better physiological status of the plant. At shooting stage, application of 100% RDF + FYM @ 10kg plant^{-1} (T_{12}) registered the maximum content of chlorophyll 'a' (0.902 and 0.908 mg g^{-1} during 2010-11 and 2011-12 respectively) and it was comparable with T_3, T_8, T_2, T_9 and T_{13} during 2010-11 and T_3, T_2, T_8, T_9 and T_{13} during 2011-12. Similarly, application of 100% RDF + FYM @ 10kg plant^{-1} (T_{12}) recorded the highest chlorophyll 'b' content (0.632 mg g^{-1}) during 2010-11. However, comparable results were observed in T_3, T_9, T_{13} and T_2. The second year results revealed that application of 100% RDF with 40% *Wellgro soil* (T_3) recorded the maximum chlorophyll 'b' content (0.636 mg g^{-1}) but it was on par with T_{12}, T_2, T_9, T_{13} and T_5. During 2010-11, the highest total chlorophyll content (1.534 mg g^{-1}) was recorded in T_{12} (100% RDF + FYM @ 10kg plant^{-1}) and it was on par with T_3 (100% RDF + 40% *Wellgro soil)*. During 2011-12, T_3 recorded the maximum total chlorophyll (1.540 mg g^{-1}), which was on par with T_{12}, T_2, T_9 and T_{13} treatments.

Nitrate reductase activity estimation is related to N assimilation efficiency and ultimately the productivity of plants. The assimilatory reduction of nitrate by plants into ammonia, which is further converted into amino acids and various nitrogenous products such as protein, is catalyzed by the nitrate reductase enzyme. In the present investigation, combined application of organic and inorganic fertilizers influenced the nitrate reductase activity at different stages of banana. Application of 100% RDF + 40% *Wellgro soil* (T_3) was found to be better in nitrate reductase activity at shooting stage (204.13 and 208.82 µg NO_2 g^{-1} h^{-1}) during 2010-11 and 2011-12, respectively. But it was comparable with T_{12}, T_9, T_2, T_8, T_{13}, T_5 and T_{11} during 2010-11 and T_{12}, T_2 and T_9 during 2011-12. The treatment T_7 registered the lowest nitrate reductase activity during both the years of study. Similarly, combined application of 100% RDF + 40% *Wellgro soil* (T_3) recorded the highest soluble protein during 2010-11 and 2011-12 (34.23 and 35.65 mg g^{-1}, respectively).

Table 1. Effect of integrated nutrient management on corm and root characteristics of banana at shooting stage

Treatments	2010-11				2011-12			
	Number of roots	Root volume (litre $plant^{-1}$)	Corm circumferene (cm)	Corm volume (litre $plant^{-1}$)	Number of roots	Root volume (litre $plant^{-1}$)	Corm circumference (cm)	Corm volume (litre $plant^{-1}$)
T_1 -100%RDF (Control)	207.77	1.30	66.67	3.53	201.30	1.35	64.00	3.80
T_2 -100%RDF +20% WS	230.20	1.49	75.67	3.83	228.33	1.53	75.67	4.36
T_3 -100%RDF +40% WS	242.57	1.60	79.17	4.10	233.00	1.58	79.17	4.73
T_4 - 75% RDF +20% WS	206.43	1.38	66.53	3.50	209.33	1.38	66.53	4.03
T_5 - 75% RDF +40% WS	225.00	1.45	72.33	3.77	219.67	1.44	72.33	4.27
T_6 -100%RDF +LOM	207.73	1.29	65.67	3.50	203.33	1.33	64.33	3.77
T_7 - 75% RDF +LOM	202.60	1.27	64.00	3.40	199.11	1.30	62.33	3.70
T_8 -100%RDF +20% WG	217.44	1.46	73.00	3.77	217.33	1.48	73.00	4.23
T_9 -100%RDF +40% WG	231.00	1.60	73.00	3.70	231.67	1.50	74.83	4.41
T_{10} -75%RDF +20% WG	211.27	1.49	69.00	3.57	212.00	1.40	69.00	4.09
T_{11} -75% RDF +40% WG	213.00	1.42	70.67	3.57	216.67	1.46	70.67	4.21
T_{12} -100%RDF +FYM	239.59	1.65	75.67	3.97	236.33	1.59	76.67	4.67
T_{13} - 75% RDF +FYM	225.53	1.49	74.33	3.73	226.67	1.46	74.33	4.13
S.Ed	4.34	0.04	3.18	0.15	5.87	0.04	3.21	0.28
CD(P=0.05)	8.95	0.09	6.55	0.30	12.13	0.10	6.64	0.59

Table 2. Effect of integrated nutrient management on growth analysis of banana at shooting stage

Treatments	2010-11					2011-12				
	LAI	CGR	RGR	NAR	AGR	LAI	CGR	RGR	NAR	AGR
T_1 - 100% RDF (Control)	3.72	11.59	12.92	29.42	37.56	3.55	12.09	13.26	28.12	39.16
T_2 - 100% RDF + 20% WS	5.42	12.17	13.07	29.10	39.42	5.20	12.80	13.34	28.57	41.48
T_3 - 100% RDF + 40% WS	5.17	15.23	14.60	31.45	49.34	5.87	13.22	13.44	28.55	42.82
T_4 - 75% RDF + 20% WS	3.76	11.63	12.99	29.30	37.70	3.54	12.03	13.10	27.80	38.98
T_5 - 75% RDF + 40% WS	4.43	12.43	13.25	29.18	40.28	4.74	12.58	13.35	28.38	40.77
T_6 - 100% RDF + WC spray	3.87	11.64	12.95	29.51	37.71	3.58	12.31	13.43	28.28	39.87
T_7 - 75% RDF + WC spray	3.25	11.59	13.00	29.55	37.54	3.31	12.05	13.28	28.03	39.04
T_8 - 100% RDF + 20% WG	4.72	12.49	13.18	29.06	40.47	4.56	12.57	13.35	28.39	40.74
T_9 - 100% RDF + 40% WG	4.65	12.50	13.14	29.23	40.51	4.92	12.76	13.37	28.54	41.34
T_{10} - 75% RDF + 20% WG	4.11	11.73	12.94	29.66	38.00	3.99	12.19	13.20	27.98	39.50
T_{11} - 75% RDF + 40% WG	4.21	11.97	13.01	28.85	38.79	4.68	12.45	13.31	28.24	40.35
T_{12} - 100% RDF + FYM	5.65	14.95	14.54	31.64	48.44	5.43	13.12	13.43	28.50	42.50
T_{13} - 75% RDF + FYM	4.55	12.55	13.23	29.19	40.67	4.74	12.57	13.24	28.24	40.71
S.Ed	0.44	0.32	1.04	0.45	1.04	0.41	0.13	0.15	0.29	0.44
CD(P=0.05)	0.91	0.66	NS	0.92	2.15	0.85	0.28	NS	NS	0.91

Table 3. Effect of integrated nutrient management on physiological parameters of banana at shooting stage

Treatments	2010-11					2011-12				
	Chl a (mg g^{-1})	Chl b (mg g^{-1})	Total chl (mg g^{-1})	NRA (µg NO_2 g^{-1} h^{-1})	Soluble protein (mg g^{-1})	Chl a (mg g^{-1})	Chl b (mg g^{-1})	Total chl (mg g^{-1})	NRA (µg NO_2 g^{-1} h^{-1})	Soluble protein (mg g^{-1})
T_1 - 100% RDF (Control)	0.853	0.487	1.340	187.67	20.40	0.856	0.499	1.355	191.10	21.45
T_2 - 100% RDF + 20% WS	0.885	0.603	1.487	201.58	28.45	0.898	0.623	1.521	205.00	27.32
T_3 - 100% RDF + 40% WS	0.891	0.630	1.521	204.13	34.23	0.904	0.636	1.540	208.82	35.65
$_4$ - 75% RDF + 20% WS	0.853	0.489	1.342	191.33	28.58	0.870	0.502	1.372	195.37	29.32
T_5 - 75% RDF + 40% WS	0.865	0.545	1.409	197.85	21.38	0.880	0.611	1.492	200.80	23.65
T_6 - 100% RDF + WC spray	0.852	0.484	1.336	187.91	20.99	0.859	0.494	1.353	191.78	21.84

T_7 - 75% RDF + WC spray	0.849	0.484	1.333	187.13	19.20	0.854	0.493	1.347	190.29	20.09
T_8 - 100% RDF + 20% WG	0.889	0.597	1.485	199.75	25.34	0.895	0.607	1.502	199.13	24.65
T_9 - 100% RDF + 40% WG	0.880	0.616	1.496	201.76	30.45	0.890	0.620	1.511	204.10	31.25
T_{10} - 75% RDF + 20% WG	0.855	0.495	1.350	192.87	23.96	0.867	0.520	1.387	196.18	24.12
T_{11} - 75% RDF + 40% WG	0.864	0.543	1.406	196.47	25.26	0.874	0.598	1.472	197.74	26.50
T_{12} - 100% RDF + FYM	0.902	0.632	1.534	203.80	33.21	0.908	0.628	1.535	206.13	32.56
T_{13} - 75% RDF + FYM	0.876	0.610	1.486	198.70	27.50	0.889	0.618	1.508	198.70	27.86
S.Ed	0.015	0.015	0.018	4.51	1.64	0.013	0.013	0.017	2.89	2.85
CD(P=0.05)	0.031	0.030	0.037	9.31	3.38	0.027	0.026	0.035	5.98	5.90

Discussion

Root and corm characteristics

Banana roots are responsible for anchorage, water and nutrient supply and exchange of various growth substances with the shoots, including plant growth hormones such as cytokinins, abscisic acid, ethylene, gibberellins and auxins and jasmonic acid (Barber, 1992; Itai and Birnbaum, 1996; and Price, 1995). In the present study, root characters such as number of healthy roots and root volume recorded at various stages revealed that application of 100% RDF with either 40% *Wellgro soil* or FYM @ 10kg plant^{-1} was superior in registering maximum values for this trait as against the remaining treatments (Table 1). Combined application of inorganic and organic sources of nutrients significantly influenced the root number of banana at all the stages of growth. In general, root number was the highest at shooting stage and declined at harvest stage of banana. The increased root number and volume might be due to improvement in soil physical conditions *viz.,* increased water holding capacity, reduction in bulk density, improved particle density, pore space, texture and soil available nutrient status which favourably influence the root growth and development and thereby indirectly promoting the growth. Organic acids produced by the applied organic manures would have a favourable loosening and flocculating effect that would have made the soil granular with better aeration, resulting in easy water absorption and might have triggered the root development in terms of root length, number and root volume as well as corm development. Similar effect was recorded earlier by Padmapriya and Chezhian (2009) in turmeric.

Better vegetative traits especially higher leaf area and higher photosynthetic activity would have effected more translocation of the nutrients to the storage organ namely the corm. Blomme et al. (2001) observed positive correlation between corm size and bunch weight. The corm is also an important storage organ for sustaining growth of the bunch and the developing sucker (Robinson, 1996).

Growth analysis

The reason for increasing leaf area index might be due to integrated application of chemical fertilizers along with organic manures, which attributed the increase in nutrient levels of NPK; especially nitrogen enhanced the vegetative growth like number of leaves and leaf area and simultaneously enhanced the leaf area index. This fact was already reported by Hazarika and Ansari (2010b) in banana. The maximum crop growth rate (CGR), relative growth rate (RGR), absolute growth rate (AGR) and net assimilation rate (NAR) was observed by the combined application of 100% RDF with 40% *Wellgro soil* or FYM @ 10kg plant^{-1}. These organic manures significantly increased the organic carbon, nitrogen and phosphorus in soil due to decomposition of organic matter. *Wellgro soil* and FYM may affect the continuous and slow release of nutrients and other organic compounds in soil which would have in turn increased the efficiency of plants with greater uptake of nutrients. A similar trend was reported by Chakravarthi (2001) in pigeonpea. All these would have led to higher photosynthetic efficiency reflecting on high yield (Gardner et al., 1988).

Physiological parameters

Any crop management practice should aim in keeping the physiological processes of the plants in an active condition so that these plants can produce more biomass with least destructive processes. Higher photosynthetic activity is a good indication of physiologically efficient plants in banana. This primarily depends upon the leaf chlorophyll content. The chlorophyll content in leaves indicates the efficiency of photosynthesis, where the solar energy is converted into chemical energy. In the present study, highest physiological parameters such as chlorophyll nitrate reductase activity and soluble protein was observed with application of 100% RDF with either 40% *Wellgro soil* or FYM @ 10kg plant^{-1} (Table 3).The applied N, P and K were utilized efficiently by the plant, which resulted in producing maximum photosynthates in terms of high biomass and translocating the assimilated materials to the developing sink. The role of nitrogen and potassium in the functioning of chlorophyll is well established. N is the chief constituent of chlorophyll, proteins and amino acids, the synthesis of which is accelerated through increased supply of N (Kohli et al., 1980). *Wellgro* organic manure contains both major and micro nutrients and contributed to the higher level of chlorophyll. This is in confirmation with Twyford and Walmsely (1974) that micronutrients especially boron, manganese, zinc and molybdenum were very essential for chlorophyll synthesis, enzyme action, photosynthesis, oxidation reduction reaction, respiration and nitrogen metabolism.

High nitrate reductase activity indicates higher levels of protein synthesis and accumulation of soluble protein. This in turn indicates that nitrogenous compounds in the plants are well utilized for various metabolic activities (Ramesh Kumar and Kumar, 2008). Moreover, major part of soluble protein consists of RUBISCO enzyme, which is a carboxylation/ oxygenation enzyme, essential enzyme for conversion of solar energy into chemical energy. Therefore, if the soluble protein is high, photosynthetic efficiency will be more.

From the field investigations, it is concluded that banana responded favourably to *Wellgro* organic manure and FYM in combination with 100% recommended dose of chemical fertilizers. Hence, combined application of 100% RDF either with *Wellgro soil* or FYM positively influenced corm and root characters and also growth and physiological parameters of banana under the soil and climatic conditions of Western zone of Tamil Nadu.

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