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Integrated nutrient management for better growth and yield of banana under Southern Sindh climate of Pakistan

Ambrin Rajput, Mehrunisa Memon*, Kazi Suleman Memon and Shamsuddin Tunio
Sindh Agriculture University, Tandojam

Abstract

Sindh is the major banana growing province in Pakistan with potential for improving yields through proper nutrient management. This study investigated the influence of integrated use of the organic amendments farmyard manure (FYM) and composted pressmud (CPM) and six mineral fertilizer treatments (500:0:0, 500:125:0, 500:187.5:0, 500:250:0, 500:250:500, 625:312.5:0 kg N: P_2O_5: K_2O ha^{-1}, respectively, designated as N, $NP_{0.5}$, $NP_{0.75}$, $NP_{1.0}$, NPK and 1.25NP (1.25 times of N and P) on the growth and yield of banana. The application of P and K fertilizers as well as the organic amendments produced significant increase in banana stem girth, number of functional leaves/plant and yield over that obtained with N alone. The effect of fertilizers became more prominent with time such that the application of either $NP_{0.75}$ or $NP_{1.0}$ produced significant increase in the growth parameters over that obtained with N only. In case of yield, the values increased by 22.6% with FYM (35.0 to 42.9 t ha^{-1}) and by 18.9% with CPM (35.0 to 41.6 t ha^{-1}) over no organic amendment treatments. Banana yield increased by 16.8% (31.6 to 36.9 t ha^{-1}) when P and K fertilizers were also applied (NPK treatment). Similarly, when FYM was added to N alone treatment, yield increased by 19.9% (31.6 to 37.8 kg ha^{-1}). When FYM was used in conjunction with NPK, the yield increased over N alone treatment by 59.4% (31.6 to 50.3 t ha^{-1}). The two organic sources produced similar results and that sub-optimal rates of P performed better when used along with FYM or CPM as compared to NPK or 1.25NP treatments alone.

Keywords: Farmyard manure, pressmud, mineral fertilizer, banana

Introduction

Banana is the major fruit crop in tropical and subtropical regions of the world. It represents the second most important fruit crop, after mango, in Pakistan, a subtropical arid country in the Asia. It covers an area of 27,200 ha with production of 140,600 tons (GOP, 2013). Sindh is the major banana growing province and contributes around 85% of the total banana area and production in Pakistan (Memon *et al*., 2010). As evident from the production data, banana yields are low by any standard. Yield estimates reported by Abro *et al*. (2008) and Memon *et al*. (2010) for district Hyderabad, Sindh, range from 6 to 44 t ha^{-1} (av. 26 t ha^{-1}) and 14.8 to 44.5 t ha^{-1} (av. 29.3 t ha^{-1}), respectively, against the potential yield of 60-80 t ha^{-1} (Memon *et al*., 2010).

Crop management, plant nutrition in particular, represents one of the major factors influencing banana yields. In spite of the fertilizer use, soils are poor in fertility with all soils deficient in N, 80-90% in P (NFDC, 2001) and 25-30% in K (Akhtar *et al*., 2003). Besides, soil organic matter contents are low (<1.0%), frequently below 0.5% (Abbas *et al*., 2012). Soil fertility status constitutes a major constraint hindering higher crop production in Pakistan and the situation is further aggravated, considering the alkaline calcareous nature of soils, imbalanced and non-judicious use of mineral fertilizers, and little or no use of organic manures.

Under low soil fertility and organic matter scenario, it becomes necessary, therefore, not only to meet the crop requirements but also improve soil fertility and organic matter levels to sustain high production levels. This assumes more importance for banana which is a heavy feeder crop requiring large amount of nutrients. In this regard, proper blend of organic and mineral sources of nutrients forms the basis for sustaining high banana yields and maintaining and improving the soil fertility at the same time.

Farmyard manure, an agro-waste, and pressmud, an agro-industrial waste, could be properly recycled into value added products (i.e. compost) and applied alone or in combination with mineral sources of plant nutrition (Memon *et al*., 2012). Pakistan has vast population of livestock, and it is estimated that only one quarter of the FYM is collected which provides 1.5 million tons of

*Email: nisamemon@googlemail.com

nutrients (FAO, 2004) in addition to organic matter and micronutrients. Pakistan sugar industry produces about 1.2 million tons of pressmud (FAO, 2004) which is a rich source of nutrients with NPK composition of 20.0, 13.5 and 9.4 g kg^{-1}, respectively (Memon *et al*., 2012), in addition to organic matter and other nutrients. This material can be beneficially utilized through co-composting with boiler ash and spentwash which needs to be examined for its potential use in an environment friendly manner. These issues are unexplored to large extent in research arena of Pakistan agriculture.

The synergistic use of organic and mineral fertilizers not only increases nutrient use efficiency but also helps in partial substitution of costly chemical fertilizers (Sharma and Dua, 1995; Jan and Noor, 2007). Research relevant to banana in Sindh or even in Pakistan is either scanty or there is no proper documentation of the data. Very few studies outline the use of various mineral fertilizer rates in combination with FYM (Shaikh *et al*., 1985; Wiebel *et al*., 1994; Memon *et al*., 2010) but certainly no studies concerning the use of pressmud as such or co-composted with organic wastes are on the record. The integration of mineral fertilizers with various organic wastes including FYM is although a common practice in other parts of the world (Bhalerao *et al*., 2009a; Kuttimani *et al*., 2013; Al-Busaidi, 2013), nonetheless, use of pressmud in any form is negligible (Patel *et al*., 2012). Many studies resulted in higher banana yields (Ziauddin, 2009; Hazarika and Ansari, 2010; Jeyabaskaran and Mustaffa, 2010) and soil fertility status (Hazarika *et al*., 2011; Vanilarasu and Balakrishnamurthy, 2014). This study was conducted to investigate the influence of integrated use of organic and mineral sources of nutrition on the growth and yield of banana.

Materials and Methods

A 2-year old banana (cv. *Musa Cavendish*) plantation established at Asim Agriculture Farm, 50 km eastward from Hyderabad near Tando Soomro, Taluka Tando Allahyar, Deh Dhoro Lakhmir (25°25'60'N and 68°31'60E; 17 m.a.s.l.), Sindh, Pakistan was used for the experiment. The mean annual rainfall is 315 mm with light cool climate in winter and warm to hot in the summer. The soils are formed from alluvial parent material.

The experiment was laid out in a split plot design involving factorial combination of three organic amendments (no organic amendment, farmyard manure and composted pressmud, designated, respectively, as control, FYM and CPM) as major split and six mineral fertilizer treatments (500:0:0, 500:125:0, 500:187.5:0, 500:250:0, 500:250:500, 625:312.5:0 kg $N:P_2O_5:K_2O$ ha^{-1}) respectively, designated as N, $NP_{0.5}$, $NP_{0.75}$, $NP_{1.0}$, NPK and 1.25NP (1.25 times of N and P) that were assigned to sub plots measuring 142 m^2 each. The treatments were replicated four times. Treatment-wise quantities of the mineral fertilizers were divided into eight equal parts and applied monthly in the form of urea, DAP and SOP. Fertilization started in the month of March 2011 and continued up till November 2011, excluding the month of June. In case of organic amendments, FYM and CPM were applied each at 20 t ha^{-1} during the month of December in 2010. All treatments received Zn in the form of $ZnSO_4.7H_2O$ at the rate of 10 kg ha^{-1} in the month of March only.

Banana growth parameters i.e. plant height, stem girth and number of leaves were recorded during May, June and July. Six plants were randomly selected and tagged from each treatment. Plant height was measured from the ground level to the tip of cigar leaf by using a marked wooden stick. Stem girth, was measured at 1m height from the ground level by using a measuring tape while number of functional leaves were simply counted for each plant. Besides, banana yield data were also recorded by each treatment for one growth cycle. The data were statistically analyzed for analysis of variance (ANOVA) and comparison of means ($p < 0.05$) by using Statistix 8.1 (Steel *et al.*, 1997).

Prior to fertilizer application, twenty five soil samples (0-15 cm) were randomly collected from the experimental area and composited to form one sample. The air-dried 2 mm soil was used to analyze some physical and chemical properties. Soil texture was determined by the hydrometer method (Bouyoucos, 1962), $pH_{1:2}$ and $EC_{1:2}$ in soil-water extract using glass electrode, soil organic matter by Walkley–Black method (Nelson and Sommers, 1982), total N by Kjeldahl's distillation (Bremner and Mulvaney, 1982) and lime by acid neutralization method (Estean *et al*., 2013). Available P was determined by Olsen's $NaHCO_3$ extraction (Olsen *et al*., 1954), followed by color development by ascorbic acid method as given by Murphy and Riley (1962). Available K was determined by extraction with 1N ammonium acetate (NH_4OAc), followed by analysis of the extract on flame photometer as described by Knudsen *et al*. (1982).

Results

Soil properties

The soil from the experimental area was a silty clay loam containing 15.0% sand, 47.8% silt and 37.2% clay (Table 1). The soil had an $EC_{1:2}$ value of 0.34 dS m^{-1}, $pH_{1:2}$ 7.71 and $CaCO_3$ content of 11.30%. The experimental soil was low in organic matter (< 0.86%) and Olsen P (< 15 mg kg^{-1} soil) (Nelson and Sommers 1982;, Olsen *et al*., 1954)

and adequate in NH_4OAc-extractable K (> 120 mg kg^{-1} soil) (Knudsen *et al*., 1982) with respective values of 0.68%, and 12.27 and 163 mg kg^{-1} soil.

Table 1: Physico-chemical properties of the experimental soil of banana field

Soil property	Value
Sand (%)	15.0
Silt (%)	47.8
Clay (%)	37.2
Textural class	Silty clay loam
$EC_{1:2}$ (dS m^{-1})	0.34
$pH_{1:2}$	7.71
$CaCO_3$ (%)	11.3
Organic matter (%)	0.68
Olsen P (mg kg^{-1})	12.27
NH_4OAc K (mg kg^{-1})	163

Nutrient composition of organic manures

Total organic C content of FYM (40.60%) was higher than that of CPM (32.30%) as given in Table 2. Among the major nutrients, both CPM and FYM contained similar levels of total N (2.07 and 2.15%) while total P content of CPM (1.76%) was higher than that of FYM (1.30%). Reverse was true in case of total K i.e. FYM contained higher percentage of K than that in CPM. The C:N ratio of FYM and CPM was 20.82 and 15.2, respectively.

Table 2: Chemical analysis of FYM and CPM before application to banana

Parameter	FYM	CPM
Organic matter (%)	74.13	56.21
Organic C (%)	40.60	32.30
Total N (%)	2.07	2.15
Total P (%)	1.30	1.76
Total K (%)	1.31	0.83
C:N ratio	20.82	15.20

Plant height

The data regarding banana plant height as affected by organic amendments and mineral fertilizer treatments are presented in Table 3. During the growth period of three months, mean plant height increased from 230.2 cm in May to 255.5 cm in July. The application of mineral fertilizers as well as organic amendments also showed increasing trend, over N only treatment, with increase in the rate of fertilizer or with application of organic amendments. However, statistical analysis of the data showed that the effects of organic amendments and mineral fertilizers as well as the interactions between organic amendments and mineral fertilizer treatments were non-significant.

Stem girth

The data in Figure 1 showed significant influence of fertilizers on banana stem girth during the growth period of three months from May to July. On an average, the values for the month of May ranged from 58.9 cm where only N fertilizer was applied to 65.6 cm with application of 1.25NP treatment. Although application of P and K fertilizers contributed to increase in plant girth but the treatment differences were not large enough to be significant until higher rate of NP (1.25NP) was applied. With progress in the growth period, the effect of fertilizers became more prominent such that the application of full rate of P (treatment $NP_{1.0}$) produced significant increase in plant girth over that obtained with N only. Addition of K (NPK treatment) or increasing $NP_{1.0}$ rate 1.25 times (1.25NP treatment) did not produce significant increase in plant girth over and above that obtained with $NP_{1.0}$ treatment. Similar results were obtained in July as well. Only exception was that it required application of P and K fertilizer along with N (NPK treatment) to produce significant increase in plant girth over that obtained with N only.

In case of organic amendments, mean stem girth increased significantly ($p < 0.05$) from 60.3 to 65.3 cm in May, 62.5 to 67.2 cm in June and 63.2 to 67.5 cm in July, respectively, with application of CPM (Figure 2). However, stem girth recorded with FYM in the month of May (62.6 cm), June (65.6 cm) and July (67.3 cm) was statistically similar to the treatments receiving CPM. Further, the effect of FYM became more prominent with the passage of time as the differences between control and FYM treatments became wider and statistically significant in July. The interaction between organic amendments and mineral fertilizer was non-significant for each month except for the month of June. Maximum plant girth of 69.8 cm was recorded with combined application of CPM and 1.25NP in the month of May. During subsequent growth, highest stem girth of 74.3 cm was recorded in June and also in July with FYM plus 1.25NP.

Number of leaves

A significant increase in number of leaves over control (N alone treatment) was observed with mineral fertilizer application (Figure 3). The values for the month of May ranged from 13.0 for N alone treatment to 15.2 leaves $plant^{-1}$ where 1.25NP was applied. Corresponding values for subsequent months were 13.4 and 19.5 (June) and 16.0 and 20.9 (July). Month-wise average showed that the number of leaves increased from 14.2 in May to 16.1 in June and 18.6 in July. The treatments N and $NP_{0.5}$ performed similarly as the differences between these treatments were statistically non-significant during the growth period from May to July.

Table 3: Effect of organic amendments and mineral fertilizers on plant height (cm) in banana during the period of May to July

Fertilizer treatment*	Organic amendment (20 t ha^{-1})			Fertilizer Mean
	May			
	Control	FYM**	CPM***	
N	211.5	219.7	227.5	219.5
$NP_{0.5}$	227.7	235.6	227.5	230.3
$NP_{0.75}$	224.5	250.9	242.8	239.4
$NP_{1.0}$	226.8	217.8	239.9	228.2
NPK	228.3	237.0	231.5	232.3
1.25NP	238.0	236.7	219.9	231.5
Organic amendment mean	226.1	232.9	231.5	230.2
	HSD		**Standard error**	
Organic amendments	NS		6.41	
Fertilizer	NS		10.48	
Organic amendments x Fertilizer	NS		18.16	
		June		
N	225.6	231.4	241.1	232.7
$NP_{0.5}$	239.5	248.5	241.4	243.1
$NP_{0.75}$	239.2	262.2	245.1	248.8
$NP_{1.0}$	241.5	227.0	248.5	239.0
NPK	243.2	252.4	248.5	248.0
1.25NP	253.8	250.7	244.6	249.7
Organic amendment mean	240.4	245.3	244.9	243.5
	HSD		**Standard error**	
Organic amendments	NS		3.75	
Fertilizer	NS		10.59	
Organic amendments x Fertilizer	NS		18.36	
		July		
N	232.3	239.5	248.0	239.9
$NP_{0.5}$	255.5	257.3	245.0	252.6
$NP_{0.75}$	254.0	257.0	246.3	252.4
$NP_{1.0}$	254.1	268.3	256.1	259.5
NPK	252.3	262.3	256.5	257.0
1.25NP	270.7	265.3	279.5	271.8
Organic amendment mean	253.1	258.3	255.2	255.5
	HSD		**Standard error**	
Organic amendments	NS		5.02	
Fertilizer	NS		9.61	
Organic amendments x Fertilizer	NS		16.64	

* N = 500 kg ha^{-1}, $P_{0.5}$ = 125 kg P_2O_5 ha^{-1}, $P_{0.75}$ = 187.5 kg P_2O_5 ha^{-1}, $P_{1.0}$ = 250 kg P_2O_5 ha^{-1}, K = 500 kg K_2O ha^{-1}, 1.25NP = 625:312.5:0 kg ha^{-1} ; ** FYM = Farm yard manure ; *** CPM = Composted pressmud

However, the picture was totally different when P rates increased and K was also included with NP. During May, the difference between $NP_{0.5}$ and NPK treatments was statistically non-significant, but with application of 1.25NP, significantly higher number of leaves was recorded as compared to $NP_{0.5}$ treatment. During the subsequent months of June and July, the response to fertilization became more prominent whereby significant increase in number of leaves was obtained with either $NP_{1.0}$ treatment (June) or with $NP_{0.75}$ (July). Inclusion of K along with NP (NPK treatment) contributed to further increase in the number of leaves. However, the differences between NPK and 1.25NP treatments were non-significant during each of the three months. This signifies that further increase in number of leaves over that obtained with NPK can only be achieved if K was applied along with 1.25NP.

A highly significant effect of organic amendments was observed on number of leaves during each of the three months, from May to July (Figure 4). The mean values for the month of May ranged from 13.4 number of leaves plant^{-1} under control to significantly higher values of 14.8 with FYM and 14.4 with CPM. The leaves plant^{-1} for the month of June were 14.2, 17.1 and 17.1 and for July 16.8, 19.0 and 19.9, respectively, in control (no organic amendment), FYM and CPM. In all the cases, the differences in number of leaves recorded for FYM and CPM were statistically non-significant.

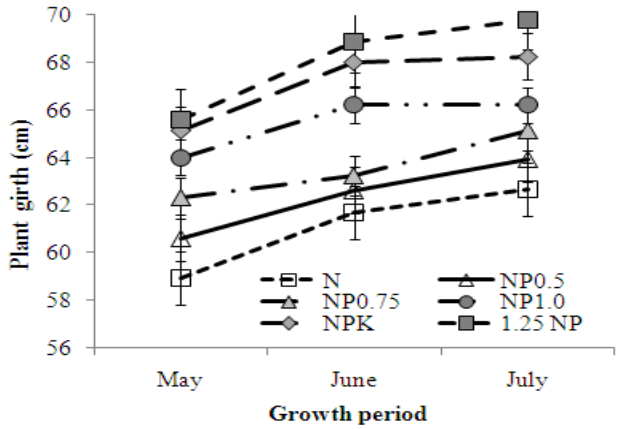

Figure 1: Banana stem girth as affected by various fertilizer treatments

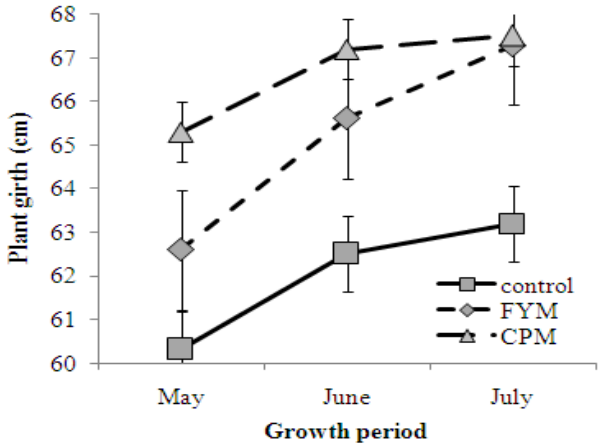

Figure 2: Banana stem girth as affected by organic amendments

Banana yield

The data in Table 4 revealed significant increase in banana yields with application of organic amendments as well as with mineral fertilizers. Minimum yield of banana (31.6 t ha^{-1}) was obtained where only N was applied. When P and K fertilizers were also applied (NPK treatment), the yield increased by 16.8% to 36.9 t ha^{-1}. Similar increases in banana yield were also obtained with FYM (37.8 t ha^{-1}) and CPM (36.1 t ha^{-1}) when applied in place of P and K fertilizers. With combined application of NPK fertilizers and FYM, the yield increased further to 50.3 t ha^{-1} which is equivalent to 59.4% increase over the yield obtained with N alone and 36.4% increase over that obtained with NPK alone. The corresponding values for combined application of NPK and CPM were 46.4 t ha^{-1}, and 47% and 25.9%, respectively.

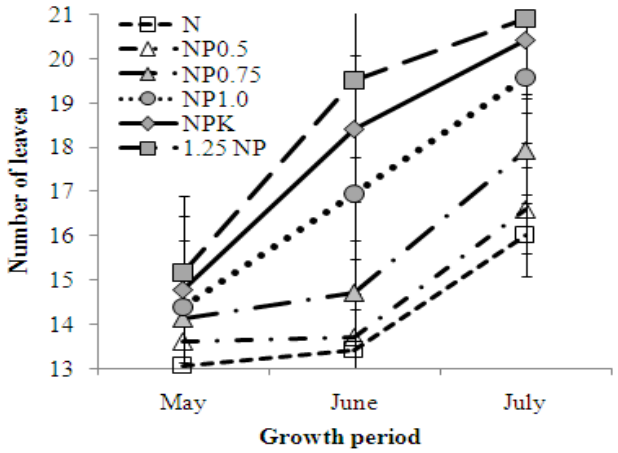

Figure 3: Number of leaves per plant as affected by various fertilizer treatments

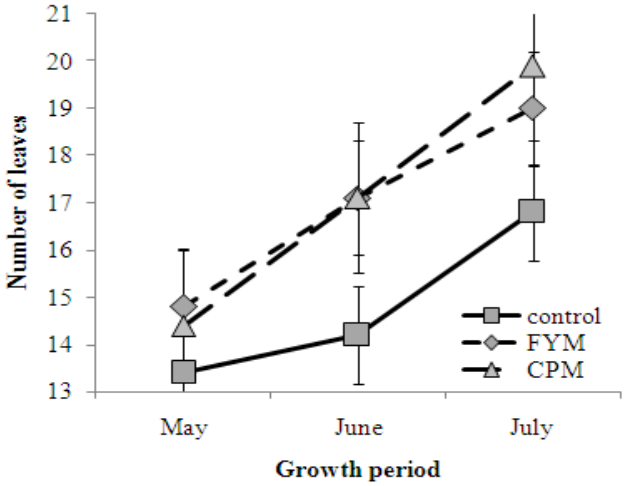

Figure 4: Number of leaves per plant as affected by organic amendments

Averaged by organic amendments, the data showed that the banana yield increased significantly from 35.0 t ha^{-1} for the treatments not receiving any organic amendment to 42.9 and 41.6 t ha^{-1} with application of FYM and CPM, respectively. Banana yield response to FYM and CPM was

similar as the treatment differences between FYM and CPM were statistically non-significant.

In case of fertilizer treatments, the average yields taken over organic amendments were 35.2 t ha^{-1} with application of N, which increased significantly to a maximum value of 44.5 t ha^{-1} for the treatment receiving NPK. Sub-optimal rates of P application (treatments $NP_{0.5}$ and $NP_{0.75}$) did not produce significant increase in banana yields until the P fertilizer rate was increased ($NP_{1.0}$ treatment). Addition of K (NPK treatment) or increasing NP rate by 25% (1.25NP treatment) did not make significant contribution to banana yield over and above that was obtained with $NP_{1.0}$ treatment. It was noted that the interactions between organic amendments and mineral fertilizers were non-significant.

Initially, there was no effect of P and K fertilizer treatments until higher rate of NP (1.25NP treatment) was applied. With advancement in growth, the effect of mineral fertilizers became more prominent such that application of P ($NP_{1.0}$ treatment) produced statistically significant increase in plant girth (June) over that obtained with N alone treatment. During the later growth period (July), it required application of either P ($NP_{1.0}$ treatment) or P and K fertilizers besides N (NPK treatment) to produce significant increase over that obtained with N only. Similar was the case for number of leaves $plant^{-1}$ with the exception that NPK or 1.25NP produced significant increase over and above $NP_{1.0}$ (June) or $NP_{0.75}$ (July) treatments. These results highlight significant contribution of P and K fertilizers as well as that of higher than $NP_{1.0}$ rates in boosting stem girth and number of leaves $plant^{-1}$. For NPK treatment, highest

Table 4: Effect of organic amendments and mineral fertilizers on banana yield (t ha^{-1})

Fertilizer treatment*	Organic amendment (20 t ha^{-1})			Fertilizer
	Control	FYM**	CPM***	Mean
N	31.6	37.8	36.1	35.2 D
$NP_{0.5}$	33.3	39.2	38.7	37.1 CD
$NP_{0.75}$	34.9	40.1	40.7	38.5 BCD
$NP_{1.0}$	35.8	42.5	44.0	40.8 ABC
NPK	36.9	50.3	46.4	44.5 A
1.25NP	37.6	47.4	43.9	43.0 AB
Organic amendment mean	35.0 B	42.9 A	41.6 A	39.8
	HSD		Standard error	
Organic amendment	3.48		-	
Fertilizer	4.35		-	
Organic amendment x fertilizer	NS		2.53	

*N = 500 kg ha^{-1}, $P_{0.5}$ = 125 kg P_2O_5 ha^{-1}, $P_{0.75}$ = 187.5 kg P_2O_5 ha^{-1}, $P_{1.0}$ = 250 kg P_2O_5 ha^{-1}; K = 500 kg K_2O ha^{-1}, 1.25NP = 625:312.5:0 kg ha^{-1}; ** FYM = Farm yard manure; *** CPM = Composted pressmud

Discussion

Growth parameters

This study highlights some of the important growth parameters viz. plant height, stem girth and number of leaves recorded as a function of time, mineral fertilizers and organic amendments during the active growth period (May to July) of banana before emergence of inflorescence. All the three parameters registered progressive increase with the passage of time from May to July. Mean values for plant height, stem girth and number of leaves $plant^{-1}$ ranged from 230.2 to 255.5 cm, 62.8 to 66.0 cm and 14.2 to 18.6 corresponding to 11.0, 5.1 and 31.0% increase in respective parameters over the growth period of three months.

Except for plant height, a significantly beneficial effect of mineral fertilizers and organic amendments was evident from the data for stem girth and number of leaves $plant^{-1}$. increase in stem girth from 58.9 to 65.1 cm (10.5%) and number of leaves $plant^{-1}$ from 13.4 to 18.4 (37.3%) occurred in May and June, respectively, as compared to N alone treatment.

Like fertilizers, a highly significant effect of FYM and CPM was also observed during each of the three months, both being equally effective in increasing the number of leaves $plant^{-1}$, while CMP was more effective than FYM in enhancing the stem girth. The benefit from organic amendments ranged, on an average, from 7.5 to 8.3 % in stem girth and from 10.5 to 20.4 % in leaves $plant^{-1}$ over this period.

Local research pertaining to the influence of banana nutrition on growth and development is scarce. Early works on banana concluded that higher dose of N (336 kg N ha^{-1}) contributed to significant increase in plant height (Jagirdar and Choudhry, 1971) and that fertilization of banana,

particularly K application, was necessary (Jagirdar *et al*., 1963). In another study, Jagirdar and Ansari (1966) reported that application of K (224 kg ha^{-1}) in association with P (336 kg ha^{-1}) or that of P alone proved conducive to better vegetative growth in the form of stouter stems.

Later, Shaikh *et al.* (1985) reported that there was no effect of NPK fertilizer treatments on any of the growth parameters viz. plant height, number of leaves $plant^{-1}$ and pseudostem circumference in first and second year of their study. Only exception was the pseudostem circumference which increased significantly during the second year when NPK rate was increased from 450-225-450 to 786-393-786 kg ha^{-1}. Given the nature of fertilizer treatments in their study, there was no way of separating out the effects of N, P and K as the NPK rates varied simultaneously in the ratio of 2:1:2 for all the treatments. In contrast to this, the treatments in current study were designed in such a way that the effects of P and K could be separated from each other and from N. In addition, the design determines the effect of 25% increase in NP rate (1.25NP, 625-312.5 kg NP ha^{-1}) against the $NP_{1.0}$ treatment.

Review of the works done elsewhere showed variable effects of NPK fertilizers on plant height, stem girth, and number of leaves $plant^{-1}$. In a 3-year field study to determine optimum rate and schedule of K for banana, Bhalerao *et al*. (2008) showed that there was no benefit in increasing the K rate from 200 to 300 g K_2O $plant^{-1}$ on plant height and stem girth. Thus, 200 g K_2O $plant^{-1}$ (which is equal to 500 kg ha^{-1} K_2O assuming 1000 plants $acre^{-1}$) was enough for optimal growth of banana. For the study conducted on N, Bhalerao *et al*. (2009b) showed that maximum plant height (216.12 cm) and stem girth (68.15 cm) were achieved with application of 250 g N $plant^{-1}$ (which is equal to 625 kg N ha^{-1} assuming 1000 plants $acre^{-1}$).

On the other hand, Al-Harthi and Al-Yahyai (2009) found that the application of NPK fertilizer over and above 600-100-500 g mat^{-1} yr^{-1} did not greatly influence leaf number and area, plant height and stem circumference. Similarly, Hegde and Srinivas (1991) observed that increasing N and K fertilization had no effect on stem girth. This was perhaps due to sufficient amounts of soil NPK to sustain vegetative growth (Al-Harthi and Al-Yahyai, 2009). Martinez (1984) reported that at the time of flowering, all the treatments produced same number of leaves (10-12 leaves $plant^{-1}$) which exceeded the lowest number of leaves (8 leaves $plant^{-1}$) required at flowering to obtain high yield.

Integrated use of mineral fertilizers and organic manures has been the subject of many studies on banana and other crops. Application of organic manures can help improve growth parameters. Sundararaju and Kiruthika (2009), Athani *et al*. (2009) and Badgujar *et al*. (2010) recorded higher pseudostem height, pseudostem girth, and total number of leaves with application of various organic manures.

Bhalerao *et al*. (2009a) observed that combined application of 100% recommended dose of fertilizers (200:40:200 g $N\text{-}P_2O_5\text{-}K_2O$) along with 10 kg FYM $plant^{-1}$ and biofertilizers improved plant height to 216.0 cm (5.5% increase) and stem girth to 70.92 cm (10.8% increase) over all other combinations of mineral and organic sources. In a similar study, Kuttimani *et al*. (2013) reported that integrated use of 100% recommended dose of fertilizer (RDF, 165-52.5-495 g NPK $plant^{-1}$) with FYM (10 kg $plant^{-1}$) significantly increased mean pseudostem girth (58.7 to 68.0 cm) and number of leaves $plant^{-1}$ (14.1 to 16.7) compared to that with 100% RDF during the years 2010-11 and 2011-12. Application of 40% Wellgro soil (organic manure product with blend of neem and non-timber forest produce) instead of FYM increased the growth parameters further to mean value of 70.0 cm pseudostem girth and 16.9 leaves $plant^{-1}$.

Yield

Application of mineral fertilizers as well as organic amendments resulted in significantly higher banana yields as compared to control (N alone treatment). Highest values were obtained with the application of NPK plus FYM and that there was no additional benefit in application of 25% more NP than $NP_{1.0}$ (1.25NP treatment) as compared to NPK treatment. FYM and CPM were equally effective in improving the yield with slightly higher values for FYM.

Addition of P contributed to increase in yield in accordance to the rate of P applied. The $NP_{1.0}$ treatment produced significant increase in banana yield over that obtained with N alone. The banana yields increased, on an average, by 26.6% from 35.2 t ha^{-1} with N alone to 44.5 t ha^{-1} with NPK. This was statistically similar to that obtained with increased rate of NP application (1.25NP treatment). Further, there was no difference between the treatments $NP_{1.0}$ and 1.25NP, presumably because no K was added to the enhanced NP rate.

While the pioneering works (Jagirdar *et al*., 1963; Jagirdar and Ansari, 1966 and Jagirdar and Choudhry, 1971) established the need for N, P, and K fertilization of banana locally, later works focused on various aspects of NPK fertilization in banana for obtaining higher yields.

Using 450-225-450 kg ha^{-1} NPK as minimum fertilizer rate, Shaikh *et al.* (1985) reported that higher NPK rates

were not effective in enhancing banana yield during first year of its application and that NPK fertilization at 786-393-786 kg ha^{-1} significantly increased banana yields during the subsequent two years, maximum increase being from 23.9 to 45.7 t ha^{-1}. Similarly, Shaikh *et al*. (1986-87) reported highest yield of Williams banana (47.35 t ha^{-1}) at NPK rate 600-200-600 kg ha^{-1}. On the basis of the works done at Sindh Horticulture Research Institute, Mirpurkhas, Pakistan, Memon and Leghari (1996) suggested 460-230-500 kg ha^{-1} yr^{-1} NPK along with 20 t ha^{-1} FYM. In the current study, highest yield of 50.3 t ha^{-1} was obtained with combined application of NPK (500-250-500 kg ha^{-1}) and FYM (20 t ha^{-1}). Increasing the NP rate by 25% (625-312.5 kg ha^{-1}) performed equally well but there was no additional benefit compared to $NP_{1.0}$ rate, presumably because K was not included in this treatment.

According to a survey of the farmer practices in Pakistan, Wiebel *et al*. (1994) reported that the farmers obtained average banana yield of 10.6 t ha^{-1} under standard fertilizer management (169-68-21 kg N-P_2O_5-K_2O ha^{-1} $year^{-1}$) and 26.7 t ha^{-1} under progressive fertilizer management (492-156-324 kg N-P_2O_5-K_2O ha $year^{-1}$) at Kot Ghulam Muhammad area Mirpurkhas. The authors clearly established that low banana yields even under progressive management were related to negative balance in K and Zn nutrition of banana.

Conjunctive use of FYM with various levels of mineral fertilizers improves soil fertility giving increased yield of the crop. Integrated nutrient management in banana is being practiced and experimented in various parts of the world. Bhalerao *et al*. (2009a) observed that combined application of N-P_2O_5-K_2O (200:40:200 g $plant^{-1}$) along with 10 kg FYM $plant^{-1}$ and *Azosprillum* and phosphate solubilizing bacteria 25g $plant^{-1}$ produced yield as high as 76.5 t ha^{-1}. Kuttimani *et al*. (2013) revealed that 100% dose of NPK (165-52.5-495 g $plant^{-1}$) when combined with 40% Wellgro soil gave maximum yield of 72.8 and 77.1 t ha^{-1}, respectively, during the two years of the study. Patil and Shinde (2013) observed even higher banana yield (85.80 t ha^{-1}) using 50% (100-80-100 g $plant^{-1}$) of N-P_2O_5-K_2O fertilizer (200-160-200 g $plant^{-1}$) in addition to FYM, *Azotobacter* (50 g $plant^{-1}$), phosphate solubilizing bacteria (50 g $plant^{-1}$) and vesicular arbuscular mycorrhiza (*Glomus fasciculatum*) (250 g $plant^{-1}$).

Conclusion

It is concluded that combined application of NPK fertilizers and organic amendments was beneficial in enhancing the growth and yield of banana and that the two organic sources, FYM and CPM, produced similar results. It was noted that sub-optimal rates of P performed better when used along with FYM or CPM as compared to NPK or 1.25NP treatments alone. Further, study indicated potential for further increase in banana yields at higher NP rates (1.25NP) which may be explored in future works by including graded rates of K along with NP.

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References

Abbas, G., J.Z.K. Khattak, A. Mir, M. Ishaque, M. Hussain, H.M. Wahedi, M.S. Ahmed and A. Ullah. 2012. Effect of organic manures with recommended dose of NPK on the performance of wheat (*Triticum aestivum* L.). *Journal of Animal and Plant Sciences* 22(3): 683-687.

Abro, S.A., K.S. Memon, F.C. Oad, I. Rajpar, A. Lashari and M.H. Siddiqui. 2008. NPK management for banana cultivation in district Hyderabad. *Life Sciences International Journal* 2(2): 66-671.

Akhtar, M.E., M.T. Saleem and M.D. Stauffer. 2003. Potassium in Pakistan Agriculture. Pakistan Agriculture Research Council, Islamabad, Pakistan. 50p.

Al-Harthi, K. and R. Al-Yahyai. 2009. Effect of NPK fertilizer on growth and yield of banana in Northern Oman. *Journal of Horticulture and Forestry* 1(8): 160-167.

Athani, S., P. Revanappa and P.R. Dharmatti. 2009. Effect of plant density on growth and yield in banana. *Karnataka Journal of Agriculture Science* 22: 143-146.

Badgujar, C.D., C.V. Pujari and N.M. Patil. 2010. Evaluation of banana cultivars under different fertilizer regimes. *Asian Journal of Horticulture* 4(2): 332-335.

Bhalerao, N.M., N.M. Patil, C.D. Badgujar and D.R. Patil. 2009a. Studies on integrated nutrient management for tissue cultured (Grand Naine) banana. *Indian Journal of Agricultural Research* (43): 107-112.

Bhalerao, V.P., C.R. Palawe and D.R. Patil. 2008. Studies on time of application and optimum dose of potassium for tissue cultured Naine banana. *Agricultural Science Digest* 28(1): 22-25.

Bhalerao, V.P., C.V. Pujari, A.R. Mendhe and A.D. Jagdhani. 2009b. Effect of different sources of nitrogen on yield attributes of banana (cv. Grand Naine). *Asian Journal of Soil Science* 4(2): 261-265.

Bhatti, I.B.M., S.J.I. Bukhari, A. Hussain and H.I. Majidano. 1995. Cultivation of Banana. Sindh

Horticultural Research Institute, Mirpurkhas, Sindh, Pakistan. p. 1-8

Bouyoucos, G.H. 1962. A recalibration of the hydrometer method for making mechanical analysis of soils. *Agronomy Journal* 43: 434-438.

Bremner, J. M. and C. S. Mulvaney. 1982. Nitrogen total. p. 595-624. *In:* Methods of Soil Analysis. Agronomy No. 9, Part 2: Chemical and Microbiological Properties, 2nd Ed. A.L. Page (ed.). American Society of Agronomy, Madison, WI, USA.

Estefan, G., R. Sommer and J. Ryan. 2013. Methods of Soil, Plant and Water Analysis: A Manual for the West Asia and North Africa Region. 3rd Ed. ICARDA, Beirut, Lebanon.

FAO, 2004. Fertilizer Use by Crop in Pakistan. Land and Plant Nutrition Management Service, Land and Water Development Division. Food and Agriculture Organization of the United Nations, Rome, Italy. p. 1-36.

GOP. 2013. Economic Survey of Pakistan 2012-2013. Government of Pakistan, Finance Division, Economic Advisor Wing, Islamabad, Pakistan.

Hazarika, B.N. and S. Ansari. 2010. Effect of integrated nutrient management on growth and yield of banana to organic manuring. *Tropical Agriculture* 133: 117-229.

Hazarika, T.K., B.P. Nautiyal and R.P. Bhattacharya. 2011. Effect of INM on productivity and soil characteristics of tissue cultured banana cv. Grand Naine in Mizoram, India. *Progress Horticulture* 43(1): 30-35.

Jagirdar, S.A.P. and A.H. Choudhry. 1971. The effect of followers and fertilizer doses on the growth and production of Cavendish banana. *The Nucleus* 8: 88-94.

Jagirdar, S.A.P. and A.R. Ansari. 1966. Effect of NPK on the growth and production of Cavendish banana. *West Pakistan Journal of Agriculture Research* 4: 4-83.

Jagirdar, S.A.P., M.A. Bhutto and A.M. Shaikh. 1963. Spacing, interval of irrigation and fertilizer application in banana. *West Pakistan Journal of Agriculture Research* 1: 5-20.

Jan, A. and M. Noor. 2007. Response of wheat to farmyard manure and nitrogen under rainfed conditions. *African Crop Science Journal* 8: 37-40.

Jeyabaskaran, K.J. and M.M. Mustaffa. 2010. Integrated nutrient management in banana. *Indian Journal of Fertilizer* 6(11): 24-31.

Knudsen, D., G.A. Peterson and P.F. Pratt. 1982. Lithium, sodium and potassium. p. 225-245. *In:* Methods of Soil Analysis. Part 2. A.L. Page (ed.). American Society of Agronomy, Madison, WI, USA.

Kuttimani, R., K. Velayudham, E. Somasundaram and N.J. Jothi. 2013. Effect of integrated nutrient management on corm and root growth and physiological parameters of banana. *International Journal of Advanced Research* 1(8): 46-55.

Al-Busaidi, K.T.S. 2013. Effect of organic and inorganic fertilizers addition on growth and yield of banana (*Musa AAA cv.* Malindi) on a saline and non-saline soil in Oman. *Journal of Horticulture and Forestry* 5(9): 146-155.

Martinez, G.A. 1984. Deternincción del area minima foliar en plátano en el trópico húmedo. *Revita ICA* 19(2): 183-187.

Memon, A.B. and N.H. Leghari. 1996. Fertilizer use in banana. Banana number: *Jadid Zaraee Khojina* 4(3): 5.

Memon, M., K.S. Memon, S. Mirani and G.M. Jamro. 2012. Comparative evaluation of organic wastes for improving maize growth and NPK content. *African Journal of Biotechnology* 11(39): 9343-9349.

Memon, N., K.S. Memon, R. Anwar, S. Ahmad and M. Nafees. 2010. Status and response to improved NPK fertilization practices in banana. *Pakistan Journal of Botany* 42(4): 2369-2381.

Murphy, J. and J.P. Riley. 1962. A modified single solution method for determination of phosphates in natural waters. *Analytic Chimica Acta* 27: 31-36.

Nelson, D.W. and L.E. Sommers. 1982. Carbon, organic carbon and organic matter. p. 539-580. *In:* Methods of Soil Analysis. Part 2. A.L. Page (ed.). American Society of Agronomy, Madison, WI, USA.

NFDC. 2001. Fertilizer Use in Pakistan. Planning and Development Division, National Fertilizer Development Center, Islamabad.

Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean. 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA Circular 939:1-9, Government Printing Office Washington D.C.

Patel, K.M., H.C. Patel, V.B. Chauhan and J.S. Patel. 2012. Effect of organic manures or chemical fertilizers on yield and quality of banana fruits cv. Basrai. *Asian Journal of Horticulture* 7(2): 420-422.

Patil, V.K. and B.N. Shinde. 2013. Studies on integrated nutrient management on growth and yield of banana cv. Ardhapuri (*Musa* AAA). *Journal of Horticulture and Forestry* 5(9): 130-138.

Shaikh, A.A., M.H. Baloch, M.S. Baig and I.B. Dehraj. 1986-87. Effect of different fertilizer doses and sources on growth and production of banana. *Sindh Journal of Agriculture Research* 6: 40-46.

Shaikh, M.R., M.A. Rana, S.I.A. Rizvi and S.A.P. Jagirdar. 1985. Effect of various NPK doses on the growth and production of Basrai banana. *Pakistan Journal of Agriculture Research* 6(3): 183-186.

Sharma, R.C. and V.K. Dua. 1995. Fertilizer management in potato based cropping system in India. *Fertilizer News* 409(5): 79-93.

Steel, R.G.D., J.H. Torrie and D.A. Dicky. 1997. Principles and Procedure of Statistic: A biometrical approach. 3rd Ed. McGraw Hill, NY, USA.

Sundararaju, P. and P. Kiruthika. 2009. Effect of bio-control agent, *Paecilomyces lilacinus* along with neem cake and botanicals for the management of *Meloidogyne incognita* on banana. *Indian Journal of Nematology* 39: 201-206.

Vanilarasu, K. and G. Balakrishnamurthy. 2014. Effect of organic manures, organic amendments and green manures in soil physiochemical properties and their impact on growth, yield and nutrient uptake of banana. *The Bioscan* 9(2): 525-529.

Wiebel, J., P. Ludders and A. Krauss. 1994. Nutrient status of banana plantations in the Indus plains of Sindh. *Pakistan Journal of Potassium Research* 10(2): 34-139.

Ziauddin, S. 2009. Integrated nutrient management studies in banana (cv. Ardhapuri). *Asian Journal of Horticulture* 4(1): 126-130.