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# STATUS AND RESPONSE TO IMPROVED NPK FERTILIZATION PRACTICES IN BANANA

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**Abstract**

Banana is a heavy feeder crop and requires high quantity of nutrients which must be supplied through fertilization to obtain optimum yield on sustainable basis. This study was conducted in order to assess banana nutrition status and its response to improved fertilizer management, especially K fertilizer. The study was conducted to evaluate NPK status of banana through soil and plant analysis and obtain quantitative data on the use of manures and mineral fertilizers along with the yield levels achieved. Field experiment involved at two locations comparing banana response to improved practice of fertilization (IP, 544-227-494 kg $N-P_2O_5-K_2O$ $ha^{-1}$ $yr^{-1}$) with that of the famer's traditional practice (FP, avg. rate 381-227-93 kg $N-P_2O_5-K_2O$ $ha^{-1}$ $yr^{-1}$). Plant and soil samples were secured during the month of March and additionally in June from grower's surveyed sites and fertilizer trials and analyzed for N, P and K. The average quantity of fertilizer nutrients used by banana growers were 437 kg N, 241.6 kg $P_2O_5$, and 15.4 kg $K_2O$ $ha^{-1}$ with average manure application of 13 ton $ha^{-1}$ and average banana yield of 29.3 ton $ha^{-1}$. Analytical data showed that leaf contents of N, P and K ranged from 1.74% to 4.32% (average = 3.00%), 0.17 to 0.29% (average = 0.24%), and 1.99 to 3.56% (average = 3.15%) respectively. Regression analysis of the data showed that the relationship between leaf N (Y) and the N rate (X) could be described by the equation of the form $Y = 0.7446+0.005X$, $R^2 = 0.96$. In case of P, the relationship was $Y = 0.209+0.0001X$ with $R^2 = 0.32$. Fertilizer response experiment showed that IP was significantly superior to FP in that it increased leaf K from 2.56% to 3.308% and banana yield from 51.2 to 60.8 ton $ha^{-1}$. However N and P contents were statistically similar under both FP and IP treatments.

## Introduction

Crop yield efficiency depends on the available nutrient status of the soil (Khan *et al*., 2009). Banana requires high quantity of nutrients which must be supplied through fertilization to obtain optimum yields. It requires nitrogen, phosphorus and potassium in large amounts for its proper growth and production as fertilization can not only improve soil nutrient status but also increase plant productivity (Guo *et al*., 2009). Regular inspection of soil nutrient status plays an important role in diagnosing nutrient deficiencies and sometimes toxicities that can affect crop growth and result in low yield. To deal with nutrition problems and determine the role of management practices, nutrient analysis of soil and plant index tissue is rather accurate, reliable and quantitative approach to diagnose and precisely correcting nutrient deficiencies or toxicities. It becomes a useful tool in diagnosing nutritional disorders and help in crop management decisions. Soil and plant leaf analysis data can be further supplemented through field experiments involving application of one or more fertilizer nutrients.

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Banana is grown over approximately 10 million hectares worldwide, with an annual production of over 81.2 million tons (Anon., 2008). It is a heavy feeder crop and requires high quantity of nitrogen, phosphorus and potassium (Lahav & Turner, 1983; Al-Harthi & Al-Yahyai, 2009; Yao *et al*., 2009). According to Wichmann (1992), total nutrient uptake in banana (Cavendish group) varies from 4-7 kg N, 0.9-1.6 kg $P_2O_5$ and 18-30 kg $K_2O$ per ton of whole bunches produced. Rivera (2004) reported that a 20 kilos bunch removes 44 g of N 5 g of P and 143.47 g of K. It has been commonly observed that banana growers emphasize more on nitrogen application followed by phosphorus and almost ignore potassium. In this way, imbalance or deficiencies of these major nutrients cause considerable damage to the plant in term of quality, stress response and yield. Moreover, application of nutrients in readily available form rapidly enhances the availability of that nutrient in the soil but all is neither taken up by plants nor remain permanently in available form (Lodhi *et al*., 2009). So, it is necessary for the growers to know the nutrient status of the banana plants and soils for better plant nutrition management and achieving better production. Split application of nitrogen fertilizer is applied three to four times a year both in tropics and sub-tropics @ 250 kg N $ha^{-1}$ but in some countries up to 600 kg N $ha^{-1}$ $yr^{-1}$ is added (Lahav & Turner, 1989). Bhatti *et al*., (1995) suggested an application 455 kg of N $ha^{-1}$ $yr^{-1}$. Further, Hongwei *et al*., (2004) and Yao *et al*., (2009) used upto 1016 kg and 900 kg N $ha^{-1}$, respectively, with higher levels of phosphorus and potassium which resulted in maximum and quality banana yields. Several years of research in Costa Rica showed that 300 to 320 kg N $ha^{-1}$ $yr^{-1}$ using eight split applications of urea consistently provided higher yield and maximum economic benefits (Lopez, 1991).

In case of phosphorus, 70 ton $ha^{-1}$ fruit yield removes 15 kg of P $ha^{-1}$ $yr^{-1}$ from the soil system. Phosphorus recommendations in banana plantations generally range upto 300 kg of $P_2O_5$ $ha^{-1}$ $yr^{-1}$ (130 kg of P $ha^{-1}$ $yr^{-1}$). More than 300 kg of $P_2O_5$ $ha^{-1}$ was also recorded by Hongwei *et al*., (2004) for maximum yields. In Pakistan an application of 227 kg $P_2O_5$ $ha^{-1}$ $yr^{-1}$ has been suggested by Bhatti *et al*., (1995).

Banana requires larger quantity of potassium for proper nutrition, growth and high production of quality bananas. It is estimated that K loss from soil in fruit harvest alone can be as much as 400 kg $ha^{-1}$ $yr^{-1}$ in a 70 ton $ha^{-1}$ crop (Lopez & Espinosa, 1998). It is customary with the growers, however, not to apply K fertilizers perhaps due to the high cost of K fertilizers. For high production and good quality of bananas, K must be supplied through fertilizers, manures etc. The rate of application in different banana producing countries ranges from 100 to 1,200 kg of $K_2O$ $ha^{-1}$ $yr^{-1}$ (80 to 1,000 kg of K $ha^{-1}$ $yr^{-1}$). Insufficient K supply reduces the total dry matter production of banana plants and the distribution of dry matter within the plant. The organ most drastically affected is the bunch, hence the importance of K in banana growing becomes more crucial if better fruit quality and yield is desired. Turner & Barkus (1980) found that while low K supply halved the total dry matter produced, the bunch was reduced by 80% and the roots were adversely affected. Hongwei *et al*., (2004) reported the highest fruit yield with 10,832 kg $K_2O$ $ha^{-1}$ along with high levels of nitrogen and phosphorus. This study was conducted in order to assess banana nutrition status and its response to improved fertilizer management, especially K fertilizer, under field conditions and obtain quantitative data on the use of manures and mineral fertilizers along with the yield levels achieved.

## Materials and Methods

This study was conducted in two parts. First part of the study was meant to evaluate NPK status of banana through soil and plant analysis. The second part involved a field experiment on two locations comparing banana response to improved practice (IP) of fertilization with that of the farmer's traditional practice (FP).

**Part-I: Banana nutrition survey and site information:** A random sample of 12 banana plantations, at least two years old, was selected in district Hyderabad (25°45' North, 68°03' East, Elevation 86 ft), one of the major banana growing areas of Sindh province, Pakistan. The sampling was done during the active growing season in the month of June. While sampling banana fields, crop management information viz. fertilization and manuring practices, and yields achieved during the last fruiting cycle were also recorded for each banana plantation. This was meant to document the information and to understand and interpret the analytical data better.

For soil sampling and analysis, 24 soil samples were obtained from 12 banana plantations by combining 10 cores each at a depth of 0-15 cm and 15-30 cm from each field sampled. These samples were secured from around the 10 randomly selected plants that were also sampled from each banana field. The soil samples were air dried, crushed, passed through 2 mm sieve and analyzed for various physico-chemical properties viz., soil texture by Bouyoucos Hydrometer method, EC and pH of 1:5 soil-water extracts, organic matter (Walkley & Black, 1934), total N by modified Kjeldahl's method, available P by Olsen's method (Olsen *et al.*, 1954) and available K by extraction with 1N ammonium acetate.

For plant sampling and analysis, "International Reference Method (MEIR)" (Martin-Prevel, 1977) was followed. For each banana field sampled, 10 plants were selected at random and the samples of the index tissue comprising 10 cm wide strips of leaf blade in the centre of the leaf and on either side of the midrib were collected from recently mature leaf (3$^{rd}$ from top) of a fully grown sucker. A composite sample was prepared by each field by combining the leaf strips obtained from 10 plants in each case. Decontamination of plant samples was done by washing them with distilled water. The samples were then dried in an oven at 70$^{o}$C, ground in a Wiley Mill and analyzed for total N, P and K (Chapman & Parker, 1961).

**Part-II: Banana field experiment:** A banana field experiment was conducted at two locations of Khundu and Saeedabad to determine the benefits of improved fertilizer management (IP), especially the use of potash fertilizers, over the traditional fertilization practiced by the farmers (FP). Each location was considered as block where two plots of equal size (each of one acre or 0.405 hectare) of fully developed 3-year old banana plantations cv. Basrai were identified. One plot was managed by using traditional fertilization practices and the other plot received improved fertilization package. Fertilization practice followed by the farmers (FP) involved average application rate of 381-227-93 kg N-$P_2O_5$-$K_2O$ $ha^{-1}$ $yr^{-1}$ while improved practice of fertilization (IP) involved application rate of 544-227-494 kg N-$P_2O_5$-$K_2O$ $ha^{-1}$ $year^{-1}$. Soil and plant sampling from FP and IP plots was done in the same way as in case of banana nutrition survey. The only exception was that the sampling was done twice during the growing season, once in March and then in June. A total of eight plant samples and 16 soil samples were secured from both the locations by combining 10 cores each at a depth of 0-15 cm and 15-30 cm from each field sampled. These samples were analyzed for N, P and K prescribing in Part-1.

Banana yields were determined by recording the weight of 10 randomly selected bunches from each treatment at each location. Assuming 2966 bunches $ha^{-1}$ $yr^{-1}$, average bunch weights were multiplied by 2966 to determine total banana yield $ha^{-1}$.

**Data analysis and interpretation:** Nutrition status of banana with respect to N, P and K was evaluated by comparing the analytical data with the established critical levels of banana. If analytical values were lower than the critical level for any of the three nutrients, banana was considered to be deficient in that nutrient. The soil analytical data and the banana management practices followed by the farmers provided supporting evidence about any nutrient deficiencies. The relationship between plant content of N, P and K and their concentration in soil was determined by coefficient of correlation (*r*) and regression analysis. Banana management information and the visual observation about each site were used to explain the situations associated with nutritional disorders in banana. The data on the effect of improved fertilizer management on banana nutrition and production were analyzed statistically and the treatment means were compared by using LSD test (Steel *et al*., 1997).

## Results and Discussion

**Part-I: Banana nutritional surveyed site information:** Soil analysis of the banana sites revealed that the soils supporting banana plantations were medium to heavy in texture (silt clay loam to clay) with clay contents ranging from 34.5 to 59.5%. The soils were non-saline with EC ranging from 0.12 to 0.23 dS $m^{-1}$, and pH from 7.10 to 8.19. The organic matter of the top soil (0-15 cm) ranged from 0.75 to 1.84% with an average of 1.02%. By comparison, the sub-soil (15-30 cm) organic matter contents were much lower than surface soil and ranged from 0.49 to 0.90%, with an average of 0.69%.

**Fertilization and manuring practices followed by banana growers:** Each grower was following its own recipe for fertilization in banana, predominantly on the basis of his own experience and perceptions (Table 1). The average quantity of various fertilizers used by banana growers was 437 kg N, 241.6 kg $P_2O_5$, and 15.4 kg $K_2O$ $ha^{-1}$ $yr^{1}$ as compared to the recommended fertilizer rates 455-227-494 kg $ha^{-1}$ (Bhatti *et al*., 1995). It clearly demonstrated that the average use of N and P was well to the mark because some growers were over-fertilizing banana with N and P fertilizers beyond what is recommended. The scenario regarding K fertilization is rather disappointing. Banana removes enormous quantity of K from soil but K fertilization is generally not practiced. The role of K in banana nutrition and yield has been emphasized in many studies in Pakistan and elsewhere (Jagirdar, 1961; Singh *et al*., 1975; Fernandez-Falcon & Fox, 1985; Wiebel *et al*., 1994; Memon & Leghari, 1996; Hongwei *et al*., 2004; Yao *et al*., 2009) but there is a lot of variation in fertilizer rates suggested in different studies. Wiebel *et al*., (1994) grouped banana management in two categories: standard and progressive on the basis of fertilizer application and weeding frequency. For Kot Ghulam Muhammad area (25°17' North, 69°14' East), they reported that average rate of N, P and K was 169-68-21 kg $ha^{-1}$ $yr^{1}$ under standard management and 492-156-325 kg $ha^{-1}$ $yr^{-1}$ under progressive management. Given the level of production, they showed a negative balance of K even under progressive management where growers were using 325 kg $K_2O$ $ha^{-1}$ $yr^{1}$.

**Table 1. Information regarding banana surveyed sites and NPK content of leaf samples secured from banana growing areas of Hyderabad.**

| Site No. | N-P-K (kg ha$^{-1}$) | Manure (tons ha$^{-1}$) | Yield in last cycle (tons ha$^{-1}$) | Nitrogen (%) | Phosphorus (%) | Potassium (%) |
|---|---|---|---|---|---|---|
| 1 | 136-57-0 | 0 | 14.8 | 3.09 | 0.21 | 3.55 |
| 2 | 633-455-0 | 11.9 | 35.6 | 3.38 | 0.27 | 3.56 |
| 3 | 395-284-185 | 11.9 | 19.8 | 2.79 | 0.26 | 3.36 |
| 4 | 511-227-0 | 14.8 | 29.7 | 3.15 | 0.19 | 3.44 |
| 5 | 237-170-0 | 0 | 14.8 | 1.88 | 0.28 | 3.44 |
| 6 | 539-427-0 | 17.8 | 34.6 | 3.41 | 0.26 | 3.16 |
| 7 | 613-114-0 | 17.8 | 34.6 | 3.76 | 0.25 | 3.26 |
| 8 | 341-0-0 | 17.8 | 39.5 | 2.44 | 0.17 | 2.19 |
| 9 | 319-427-0 | 17.8 | 44.5 | 2.18 | 0.29 | 1.99 |
| 10 | 198-341-0 | 11.9 | 29.7 | 1.74 | 0.22 | 3.26 |
| 11 | 635-170-0 | 20.8 | 34.6 | 3.90 | 0.27 | 3.36 |
| 12 | 682-227-0 | 14.8 | 19.8 | 4.32 | 0.25 | 3.26 |
| Minimum | 136-0-0 | 0 | 14.8 | 1.74 | 0.17 | 1.99 |
| Maximum | 682-455-185 | 20.8 | 44.5 | 4.32 | 0.29 | 3.56 |
| Average | 437-241.6-15.4 | 13 | 29.3 | 3 | 0.24 | 3.15 |
| Stdev. | | 6.75 | 9.82 | 0.82 | 0.04 | 0.51 |

Farm yard manure application is the regular and common practice of banana growers. Interview with the banana growers revealed that the average quantity of manure application was 13 ton ha$^{-1}$ (Table 1). Except for the two growers where banana was not thriving well, all the growers were applying manure. For Kot Ghulam Muhammad area, Wiebel *et al*., (1994) reported that application of FYM (12 ton ha$^{-1}$) was a common management practice of only one grower out of a sample of 12 growers. According to the recommendations proposed by Memon & Leghari (1996), banana should be manured @ 9.8 ton ha$^{-1}$. In the current study, average manure application rate was somewhat lower than the previously suggested rate. It should be noted, however, that all growers do not follow yearly schedule for application of manure.

For any farming effort, ultimate interest of the grower is to realize high production and profitability from the farming enterprise. The data in Table 1 showed that banana yields varied considerably from one grower to the other. The production ranged from 14.8 to 44.5 ton ha$^{-1}$ and averaged to 29.3 ton ha$^{-1}$. Comparison of yield level with fertilizer rate showed that the lowest yield of 14.8 ton ha$^{-1}$ corresponded to the lowest fertilizer rates. However, maximum yields may not necessarily be related to the maximum rate of fertilization because crop yield is a function of many variables. In case of banana, the level of management, plant population, fertilization and manuring practices etc., play a leading role in determining the production levels. According to Bhatti *et al*., (1995), average bunch weight of banana varied from 18 to 25 kg. Accordingly, yields of 60 to 80 ton can be obtained per hectare. For Kot Ghulam Muhammad area, Wiebel *et al*., (1994) reported that average banana yield was 10.6 ton ha$^{-1}$ under standard management and 26.7 ton ha$^{-1}$ under progressive management. Hongwei *et al*., (2004) reported the highest yield of 39.3 ton ha$^{-1}$ under optimum fertilization practices. Yao *et al*., (2009) reported yield of 40.5 ton ha$^{-1}$ from mother and 58.2 ton ha$^{-1}$ from daughter banana plantations. Angeles *et al*., (1993) reported that 16% of the 915 observations assembled from 26 published and non-published sources were from high yielding banana population yielding >70 ton ha$^{-1}$. These data essentially point out that there is great potential to increase the productivity of banana through better management and appropriate fertilization practices.

**Leaf NPK Status of banana plantations:** Leaf N content ranged from 1.74% to 4.32% with an average value of 3.0% (Table 1). Based on an average N content, one would get the impression that nitrogen nutrition of banana is well above the critical level of 2.6% N as proposed by Lahav & Turner (1983). Detailed examination of the data, however, revealed that N content was less than 2.6% at 4 of the 12 sites (Site No. 5, 8, 9 and 10). Different workers have proposed different critical levels of N (in 3$^{rd}$ leaf of banana) which range from 1.81 to 4.0% and an average of 3.03% (Angeles *et al*., 1993). According to this criterion, samples from 5 sites were below the critical level of 3.03% N. Wiebel *et al*., (1994) also used the critical level of 2.6% for interpreting the leaf analysis data for the banana grown in Kot Ghulam Muhammad area. They reported that leaf N content was 2.23% under standard management where growers were applying, on an average, 169 kg N ha$^{-1}$ yr$^{-1}$. Under progressive management where average fertilizer rate was 492 kg N ha$^{-1}$ yr$^{-1}$, the leaf N content was 2.69%.

These data point out to the fact that the level of management and the fertilization rates have lot to do with the nutritional status of banana. In this study, fertilization rates ranged from as low as 136 to a maximum of 682 kg N ha$^{-1}$ yr$^{-1}$. Correlation between N application rates and the leaf N status showed a highly significant correlation with $r = 0.83$. Regression analysis of the data showed that the relationship between leaf N (Y) and the N rate (X) can be described by the equation of the form Y = 1.44 + 0.0036X (Fig. 1a). The coefficient of determination i.e., $R^2$ was 0.69 which means that 69% of the variability in the data could be explained by the above equation. This is despite the fact that the samples were drawn from the plantations with a wide range in their soil properties and diverse management practices. A close look at the findings showed that one data point at the low end of the regression line was an outlier and affected the shape of the best fitting line (Fig. 1a). The data pertained to Site 1 receiving minimum rate of N (136 kg N ha$^{-1}$ yr$^{-1}$) had a comparatively high value of leaf N. Examination of the field notes revealed that the plant population at Site 1 was no more than 50% of the normal because of BTV problem. In practical terms, it meant that the lowest rate of N applied at this site was not actually so because it was being applied only to the existing plant population of about 50%. This resulted in higher leaf N (3.09%) than what was anticipated on the basis of actual N rate per hectare. Therefore, the data for Site 1 were excluded from the regression analysis. Accordingly, the relationship between Y and X can be described by the equation: Y = 0.744 + 0.005X, $R^2 = 0.96$ (Fig. 1b). On the basis of this equation, it will require application of 383 kg N ha$^{-1}$ yr$^{-1}$ to achieve leaf N content of 2.6% i.e. critical level of N in 3$_{rd}$ leaf of banana as proposed by Lahav & Turner (1983).

Survey of P status of the same banana plantations showed that leaf P contents ranged from 0.17 to 0.29% (Table 1) - lowest value was obtained for the site not receiving any P fertilizer and highest for the one fertilized @ 427 kg $P_2O_5$ ha$^{-1}$ year$^{-1}$. There was a significant correlation ($r = 0.57$) between the rate of P application and leaf P content. The leaf P content data were compared with the critical level of 0.2% as given by Lahav & Turner (1983). Based on this criterion, there were only two samples which were below 0.2%. One sample containing 0.17% P came from the plantation (Site 8) where no P fertilizer had been applied. The other sample was very close (0.19% P) to the critical level where P application rate was 227 kg ha$^{-1}$ yr$^{-1}$. While P application rate was sufficient according to the recommendation of 227 kg ha$^{-1}$ yr$^{-1}$ proposed by Memon & Leghari (1996), P nutrition status was still marginal as indicated by leaf analysis. This was not the case with other plantation (Site 12) where leaf P content was 0.25% for the same rate of P application i.e., 227 kg ha$^{-1}$ yr$^{-1}$. The discrepancy could be due to one or more of the following reasons: level of management, schedule of P fertilizer application

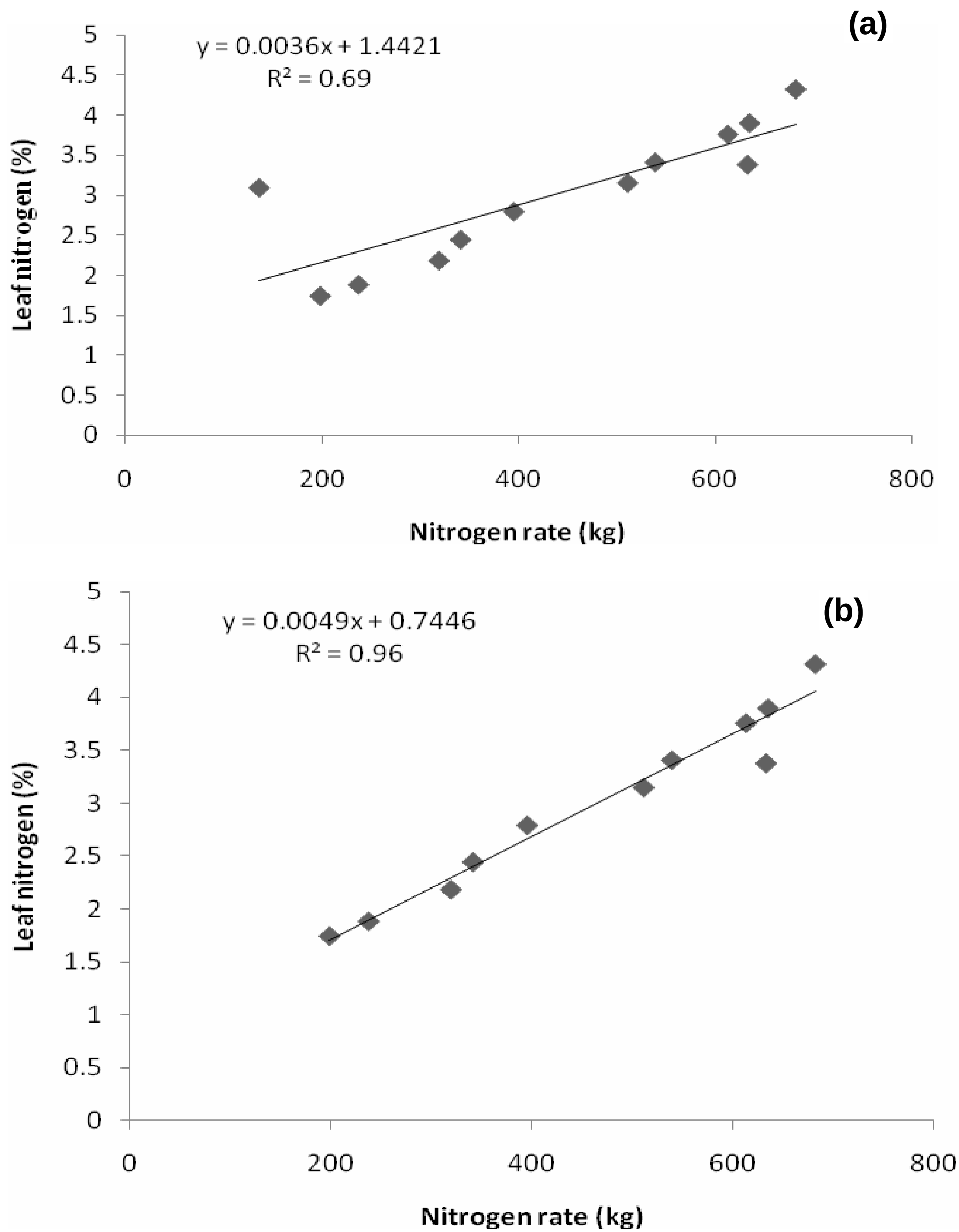


Fig. 1. Regression equation showing relationship between nitrogen application rate and leaf N content (%) from different banana growing fields of Hyderabad

and the sensitivity of the index tissue sampled. For banana plantations of Kot Ghulam Muhammad area, Wiebel *et al*., (1994) reported that average leaf P content was 0.21% under standard management receiving 68 kg $P_2O_5$ kg $ha^{-1}$ $yr^{-1}$ which increased to 0.23% under progressive management receiving 156 kg $P_2O_5$ kg $ha^{-1}$ $yr^{-1}$. Regression analysis of the data showed that the relationship between P rate (X) and leaf P content (Y) can be described by the equation of the form Y = 0.209 + 0.0001X with $R^2$ = 0.32 (Fig. 2). It means that only 32% of the variability in the leaf P contents can be explained by the rate of P application. Major portion of the variability, therefore, remains unexplained. It may be related to soil properties, soil P status, manuring practices, the level of management and the reliability of leaf tissue used for plant sampling.

Leaf analysis of banana plantations showed that K content varied from 1.99% to 3.56% (Table 1). No relationship can be worked out with the rate of K application as there was only one grower who applied $K_2O$ @ 185 kg $ha^{-1}$ $yr^{-1}$ to banana. Comparison of the leaf K contents with critical level of K showed that two samples were considerably below the critical level of 3.0% as given by Lahav & Tuner (1983). For Kot Ghulam Muhammad area, Wiebel *et al*., (1994) reported that K content of banana was below the critical limit under both the standard (2.61% K) and progressive (2.71% K) management practices. In this study, majority of the samples showed K concentration above the critical value of 3.0%. It should be noted, however, that different workers have suggested different critical levels of K which range from 1.66 to 5.40% K with an average of 3.4% (Angeles *et al*., 1993). Therefore, Angeles *et al*., (1993) used critical level of 3.4% as criteria for high yielding population. By using this critical level, majority of the banana plantations in this study were considered below the critical level. This signifies the need for application of K fertilizers for better nutrition and high yield of banana. It is well established fact that K improves the quality of banana, in addition to its role in increasing banana production.

Based on the facts revealed from this survey and a lot of variation reported about fertilizer rates, authors were encouraged to conduct a field trial to evaluate farmer's nutrition practices with improved practices and expect that it may improve banana production and thus convince farmers to consider balanced fertilization of their orchards.

**Part-II: Banana field experiment:** The soils at the two experimental sites were clay loam, with similar clay content of 34.9 to 39.9%. Both soils were non-saline (EC = 0.15 to 0.19 dS $m^{-1}$) with pH values of less than 8.00 (7.71 to 7.83).

The data in Table 2 showed that improved practice of fertilization (IP, 544-227-494 kg $N\text{-}P_2O_5\text{-}K_2O$ $ha^{-1}$ $yr^{-1}$) was superior to farmer's practice (FP, avg. rate 381-227-93 kg $N\text{-}P_2O_5\text{-}K_2O$ $ha^{-1}$ $yr^{-1}$) in that it significantly increased soil available phosphorus from 5.86 to 9.75 mg $kg^{-1}$ and available potassium from 0.450 to 0.516 me 100 $g^{-1}$. Nitrogen was not affected by any fertilizer practice and sampling time. However both nitrogen and phosphorus were greatly affected by soil depth, with top soil (0-15 cm) having significantly higher percentage of nitrogen (av. 0.085%) and available phosphorus (av. 9.96 mg $kg^{-1}$) as compared to that in sub-soil (15-30 cm).

**Effect of traditional and improved fertilizer practices on leaf NPK status:** The data in Table 3 showed that leaf N and P contents were not affected by sampling time and fertilization practices. The values for leaf N and P contents showed that nitrogen nutrition of banana was well even under FP i.e., above critical level of 2.6% N and 0.2% of P as proposed by Lahav & Turner (1983; 1992). Wiebel *et al*., (1994) also used the critical level of 2.6% for interpreting the leaf analysis data for the banana grown in Kot Ghulam Muhammad area. They reported that leaf N content was 2.23% under standard management where growers were applying 169 kg N $ha^{-1}$ $yr^{-1}$. Under progressive management where fertilizer rate was 492 kg N $ha^{-1}$ $yr^{-1}$, the leaf N content was 2.69%.

**Table 2. Total nitrogen, available phosphorus and potassium contents of top (0-15 cm) and sub soil (15-30 cm).**

| Soil depth | Farmer's practice (FP) | | | Improved practice (IP) | | | Depth mean |
|---|---|---|---|---|---|---|---|
| | March sampling | June sampling | Mean | March sampling | June sampling | Mean | |
| | **Total Nitrogen (%)** | | | | | | |
| 0-15 | 0.080 | 0.082 | 0.081 | 0.088 | 0.089 | 0.089 | **0.085 A** |
| 15-30 | 0.063 | 0.069 | 0.066 | 0.066 | 0.081 | 0.073 | **0.070 B** |
| Mean | 0.071 | 0.076 | **0.073** | 0.077 | 0.085 | **0.081** | |
| **LSD = 0.0008** | **SE= 3.724E-03** | | | | | | |
| | **Available Phosphorus (Olsen, mg kg$^{-1}$)** | | | | | | |
| 0-15 | 7.30 | 8.15 | 7.72 | 12.00 | 12.40 | 12.20 | **9.96 A** |
| 15-30 | 3.60 | 4.40 | 4.00 | 7.90 | 6.70 | 7.30 | **5.65 B** |
| Mean | 5.45 | 6.27 | **5.86 B** | 9.95 | 9.55 | **9.75 A** | |
| **LSD= 1.856** | **SE=0.843** | | | | | | |
| | **Available Potassium (Amm. acetate extractable, me 100 g$^{-1}$)** | | | | | | |
| 0-15 | 0.460 | 0.50 | 0.480 | 0.545 | 0.545 | 0.545 | **0.512** |
| 15-30 | 0.435 | 0.405 | 0.420 | 0.460 | 0.515 | 0.488 | **0.454** |
| Mean | 0.447 | 0.452 | **0.450 B** | 0.502 | 0.530 | **0.516 A** | |
| **LSD= 0.059** | **SE= 0.027** | | | | | | |

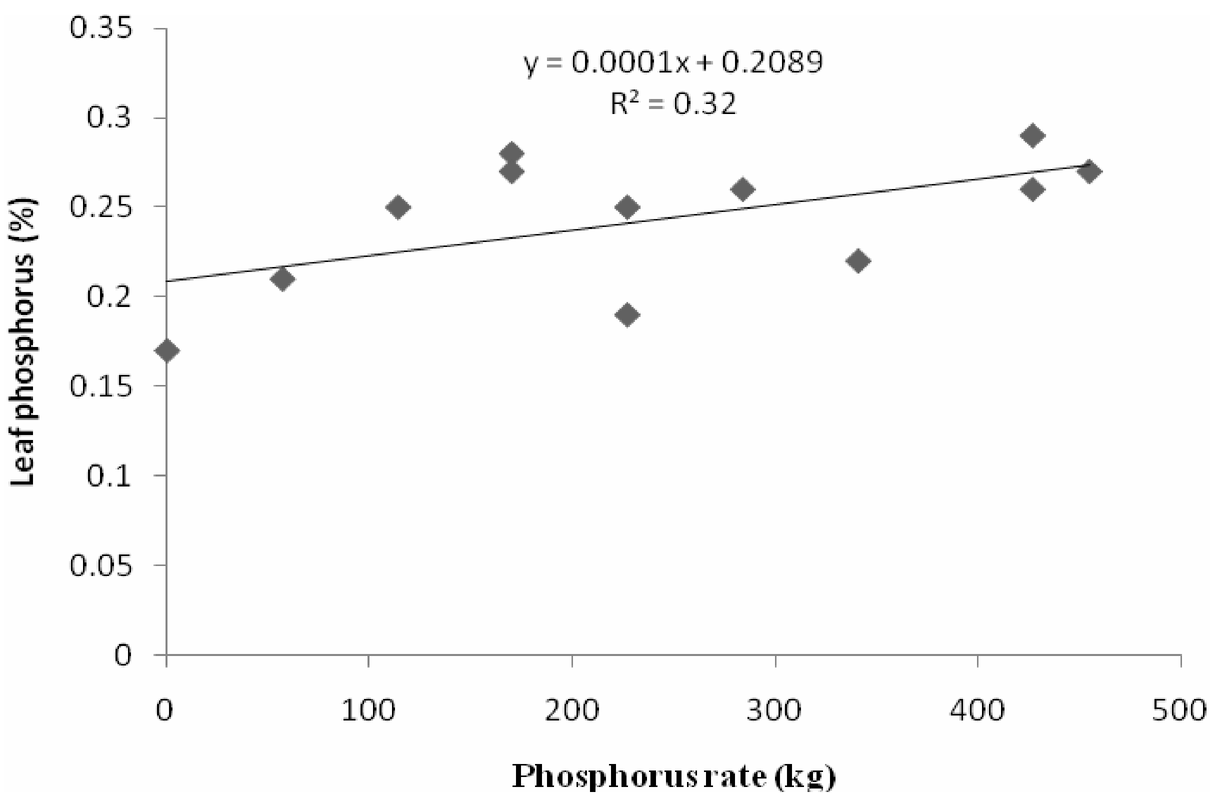


Fig. 2. Regression line showing phosphorus application rate and leaf P content (%) from different banana growing fields of Hyderabad.

Leaf P contents varied from 0.21% to 0.24% with mean value of 0.225% under FP and 0.235% under IP (Table 3). These values were more than the critical level of 0.20% (Lahav & Turrner, 1983; 1992). In other words, fertilization and manuring practices were according to the banana requirements. Comparison between FP and IP showed that leaf P contents were similar under IP than under FP. This was expected because average P rates under FP and IP were rather similar. The effect of time of sampling on leaf P content was inconsistent and appeared to be better controlled by P rate and soil status than by the sampling season. Wiebel *et al*., (1994) reported that average leaf P content was 0.21% under standard management receiving 68 kg $P_2O_5$ $ha^{-1}$ $yr^{-1}$ which increased to 0.23% under progressive management receiving 156 kg $P_2O_5$ $ha^{-1}$ $yr^{-1}$.

Potassium fertilization of banana under IP showed a highly significant increase in K content of leaf (Table 3). Leaf K values increased from 2.56% under FP to 3.31% under IP which could be attributed as a response to K fertilization. Under FP, growers used only up to 124 kg $K_2O$ $ha^{-1}$ $yr^{-1}$ against K application rate of 494 kg $K_2O$ $ha^{-1}$ $yr^{-1}$ under IP. It was further observed that leaf K contents were below the critical level of 3.0% (Lahav & Turner, 1983; 1992) under FP, and considerably higher than this critical limit under IP. For Kot Ghulam Muhammad area, Wiebel *et al*., (1994) reported that K content of banana was below the critical limit under both the standard (2.61% K) and progressive (2.71% K) management practices. It is added that different reports suggest different critical levels of K which range from 1.66 to 5.40% K with an average of 3.4% (Angeles *et al*., 1993). Therefore, Angeles *et al*., (1993) used critical level of 3.4% as criteria for high yielding population. By using this critical level, majority of the banana plantations in this study would be considered below the critical level. This signifies the need for application of K fertilizers for better nutrition and high yield of banana. It is well established fact that K improves the quality of banana, in addition to its role in increasing banana production.

**Effect of traditional and improved fertilizer practices on banana yield:** The data in Table 4 depicted that average bunch weight was 17.25 kg under FP and 20.5 kg under IP and the difference between FP and IP treatments was significant ($t = 4.8$, probability of $t = 0.0009$).

Based on plant population $ha^{-1}$, there will be 2966 banana bunches $ha^{-1}$ $year^{-1}$. Total fruit yield thus amounted to 51.2 ton $ha^{-1}$ under FP and 60.8 ton $ha^{-1}$ under IP treatments. Expressed on percentage basis, there was 18.8% increase in fruit yield due to improved practice (IP) of fertilization. The data clearly showed that IP contributed to improved banana nutrition, yield and net profit of the grower. According to Bhatti *et al*., (1995), average bunch weight of banana varied from 18 to 25 kg. Accordingly, yields of 60 to 80 ton $ha^{-1}$ can be obtained. Yao *et al*., (2009) reported optimum fertilization i.e., 900-270-1080 kg N-$P_2O_5$-$K_2O$ $ha^{-1}$ for mother banana plants to obtain yield of 40.5 ton $ha^{-1}$ and 825-248-990 kg N-$P_2O_5$-$K_2O$ $ha^{-1}$ for the daughter plant to obtain 58.2 ton $ha^{-1}$. Hongwei *et al*., (2004) reported highest K rate of 1,832 kg $K_2O$ $ha^{-1}$ produced a maximum yield of 39.3 ton $ha^{-1}$, which was 66% higher than the control (no K application) and nearly 42% higher than farmer practice (576 kg $K_2O$ $ha^{-1}$). Zake *et al*., (2000) reported that application of 200 kg K $ha^{-1}$ more than doubled the yield, which showed that potassium deficiency in farmers' fields could be one of the factors responsible for decline in banana production in the country. For Kot Ghulam Muhammad area, Wiebel *et al*., (1994) reported that average banana yield was 10.6 ton $ha^{-1}$ under standard management and 26.7 ton $ha^{-1}$ under progressive management.

**Table 3. Leaf nitrogen, phosphorus and potassium contents as affected by farmers' and improved practice of fertilization.**

| Sampling month | Fertilizer practices | | Mean |
|---|---|---|---|
| | Farmer's practice (FP) | Improved practice (IP) | |
| | **Nitrogen (%)** | | |
| March | 3.720 | 4.100 | 3.910 |
| June | 2.470 | 3.630 | 3.050 |
| Mean | 3.095 | 3.865 | |
| **SE = 0.39** | | | |
| | **Phosphorus (%)** | | |
| March | 0.210 | 0.240 | 0.225 |
| June | 0.240 | 0.230 | 0.235 |
| Mean | 0.225 | 0.235 | |
| **SE = 0.01** | | | |
| | **Potassium (%)** | | |
| March | 2.525 | 3.210 | 2.868 |
| June | 2.595 | 3.405 | 3.000 |
| Mean | **2.560 A** | **3.308 B** | |
| | **LSD= 0.242** | **SE= 0.087** | |

**Table 4. Bunch weight (kg/bunch) of banana as affected by farmer's and improved practice of fertilization.**

| Bunch No. | Fertilization Practices | |
|---|---|---|
| | Farmers's practice (FP) | Improved practice (IP) |
| 1 | 24 | 27 |
| 2 | 19 | 26 |
| 3 | 13 | 15 |
| 4 | 16.5 | 18.5 |
| 5 | 15.5 | 17 |
| 6 | 28 | 35.5 |
| 7 | 14.5 | 17.5 |
| 8 | 11 | 12.5 |
| 9 | 12.5 | 15.5 |
| 10 | 18.5 | 20.5 |
| Minimum | 11 | 12.5 |
| Maximum | 28 | 35.5 |
| Average | 17.25 | 20.5 |
| Std. Dev. | 5.3 | 7.0 |
| CV% | 30.7 | 34.1 |
| t value | 4.8 | |
| Prob. of t | 0.0009 | |

## Conclusion

The results of this study revealed that leaf analysis ($3^{rd}$ leaf from top) for N and K can be used to indicate N and K nutritional status of banana. Leaf analysis for P was, however, less indicative of the P nutritional status of banana and requires further studies to reflect more clearly its nutrition status. Fertilizer response experiments showed that improved practice of fertilization (544-227-494 kg $N\text{-}P_2O_5\text{-}K_2O$ $ha^{-1}$ $year^{-1}$) was superior to farmer's practice (avg. rate 381-227-93 kg $N\text{-}P_2O_5\text{-}K_2O$ $ha^{-1}$ $year^{-1}$) as it increased leaf K and banana yield significantly. Leaf N and P contents were, however statistically similar under both FP and IP practices.

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