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NUTRIENT COMPOSITION OF BANANA FRUIT AS AFFECTED BY FARM MANURE, COMPOSTED PRESSMUD AND MINERAL FERTILIZERS

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Abstract

Major area under banana cultivation in Pakistan consists of a single cultivar "Dwarf Cavendish" called "Basrai". Quality of banana relies on the available nutrients in soil. Under poor fertility and organic matter scenario coupled with high requirement of banana, this study evaluated the combined effect of organic (farm manure and composted pressmud) and inorganic (NPK) sources of nutrients on nutrient composition of locally grown banana. Application of full NPK (500-250-500 kg ha^{-1}) increased the fruit P (0.08-0.12%), K (0.77-1.50%) and Zn (1.74-2.17 mg kg^{-1}) over full N and the respective values further increased to 0.14 and 0.22%, 2.28 and 1.79% and 2.42 and 2.21% with farm manure and composted pressmud additions. Moreover, there was a non-significant increase in N and significant one in Cu and Fe. There was no additional benefit of 1.25 NP. In fact, the higher rates i.e. full NPK and 1.25 NP reduced the micronutrient contents of fruit due to dilution effect. However, the P requirement was same even with application of organic sources. The regression analysis of the yield data with fruit nutrients (N, P, K, Cu, Fe, Mn and Zn) showed a highly significant relationship with respective "r" values of 0.65, 0.66, 0.75, 0.48, 0.65, 0.71 and 0.73. The integrated use of mineral fertilizers and organic amendments resulted in enhanced banana fruit nutrients and highlights the advantage of conjunctive use over their separate applications.

Key words: Banana fruit, N, P, K, Cu, Fe, Mn, Zn, Pressmud and farm manure

Introduction

Banana fruit is important source of nutrients containing polysaccharides, sugars, vitamins A, C, B6 and other minerals with traces of fat as well as beneficial health properties and reduced risk for some forms of cancer, heart disease, stroke and other chronic ailments due to the presence of antioxidants and biologically active ingredients (Anon., 2006; Hui *et al*., 2006; Lecerf, 2008; Park *et al*., 2011). The quality of banana fruit is based on its nutrient composition. The ability of crop to absorb nutrients from soil plays a major role in the nutrient composition of food crop.

Banana demands greater quantities of N, P and K in addition to smaller quantities of micronutrients. Nitrogen is very important during first 4-6 months for vigorous growth of plant and eventually the improvement in yield and yield forming parameters (Bhalerao *et al*., 2009). Phosphorus is important in fluorescence setting and growth of healthy rhizomes and potassium for fruit quality (Bhalerao *et al*., 2009). The nutrients i.e. Ca, Mg and S are normally not applied in alkaline calcareous environment of Pakistan due to their abundance. However, the lower quantities of Ca may cause peel splitting and that of magnesium create disturbance in phyllotaxy, where as low S contents show stunt growth and increased N uptake (Borges *et al*., 2002). Sufficient quantities of micronutrients are essential and the lower contents of B may reduce the weight and size of bunch, Cu is required for defense mechanism, Fe deficiency causes interveinal chlorosis, Mn physically protects the plant and Zn helps in protein synthesis (Cordeiro & Borges, 2000).

Banana, being major fruit crop of Sindh province, contributes 87 and 89% of the respective total area and production in Pakistan. Sindh produced 101725 tons of bananas from 26,298 hectares of land during 2014-15 (Anon., 2015). District Tando Allahyar contributes a major share among the banana cultivating zones i.e., Khairpur, Badin, Hyderabad, Mirpurkhas and Sanghar of Sindh with average yield of 36.46 t ha^{-1} during 2014 (Anon., 2015). Banana growing areas are mainly located in the Indus Delta zone of Sindh. Climatic conditions, particularly temperature and light intensity have significant effect on nutritional quality of fruits (Mozafar, 1994). All soils are deficient in N, 80-90% in P (Memon *et al*., 1992; Anon., 2001) and 25-30% in K (Akhtar *et al*., 2003). Besides, soils frequently being below 0.5%, are low (<1.0%) in organic matter content (Abbas *et al*., 2012). This coupled with alkaline calcareous nature of soils, imbalanced use of inorganic fertilizers and little or no use of organic manures leads to depletion of soil fertility; a major drawback for higher crop production in Pakistan.

Nutrient composition of banana fruit depends on the available nutrients in soil. Under low fertility and organic matter situation and notably the high requirement of banana, combined use of organic and inorganic sources of fertilization seems to be the best option. Farm manure and pressmud are locally generated wastes containing 1.4 and 2.0% N, 0.29 and 1.35% P and 2.1 and 0.94% K, respectively. The pressmud compost after treatment with urea had more or less equal amounts of N, P and K (1.94, 1.46, 0.99%) contents (Memon *et al*., 2012). The synergistic effects of organic and inorganic nutrient sources enhance the plant use efficiency with less input cost (Sharma & Dua, 1995).

The studies outlining the use of inorganic fertilizers with farm manure (Shaikh *et al*., 1985; Wiebel *et al*., 1994; Memon *et al*., 2010) on banana are scanty and yet there are no studies concerning the use of pressmud with and without composting. Even those outside Pakistan also relate to inorganic fertilizers and farm manure (Bhalerao *et al*., 2009; Kuttimani *et al*., 2013; Al-Busaidi, 2013) with almost no studies (Patel *et al*., 2012) on pressmud. Combined use of organic and inorganic sources resulted in better banana yields (Ziauddin, 2009; Hazarika & Ansari, 2010; Jeyabaskaran & Mustaffa, 2010) and fertility of soil (Hazarika *et al*., 2011; Vanilarasu & Balakrishnamurthy, 2014). The analysis and nutrient composition of banana fruit is not common practice in Pakistan. There is no specific work carried out on banana nutrition as a result of combined nutrient management with special reference to farm manure and composted pressmud. Ismail *et al*. (2011) reported that the edible portion of banana Hyderabad, Sindh Pakistan contained K (7.25), Na (3.70), Ca (3.20), Mg (3.16), Cu (0.11), Fe (16.3), Mn (0.116), Co (0.1059) and Zn (0.11) mg 100 g^{-1}. Zahir *et al*. (2009) reported Cu (1.42), Fe (16.5), Mn (0.037) and Zn (0.785) ug g^{-1} contents of banana fruit collected from local Karachi market of Sindh province. Studies conducted by Attia *et al*. (2009) showed that 25% P_2O_5 + bio (phosphate solublizing bacteria) increased fruit N (1.7 and 1.59 %), P (0.124 and 0.115 %), K (2.25 and 3.02 %), Fe (23.87 and 22.30 mg kg^{-1}), Mn (1.14 and 0.92 mg kg^{-1}), and fruit Zn (3.37 and 2.51 mg kg^{-1}). The combined sources for nutrient management in banana, is a new topic in research arena of Pakistan. The work was undertaken to test the nutrient composition of banana as a result of farm manure, composted pressmud and inorganic fertilizers.

Material and methods

Description of the experimental area: Tando Soomro, located in district Tando Allahyar (25°25’60’N, 68°31’60’E, elevation 56 ft./17 m) is very rich in terms of agriculture. Soils of the area have originated from mixed alluvium parent material having flat topography, air-dried-tropical climate with 150-200 mm mean annual rainfall and temperatures of 38°C. Sugarcane, cotton, wheat and onions are some of the common cultivation practices of the area, including mango and banana orchards which are exported to Iran, Afghanistan, Middle East, Europe and North America. Established banana (cv. *Musa Cavendishi*) plantation (2 years old), 50 km eastward from Hyderabad near Tando Soomro was selected for the study. Properties of experimental soil and organic wastes used are provided in Table 1.

Experiment details: The field experiment was carried out using split plot design involving factorial combination of organic sources of nutrients (control, farm manure and composted pressmud) as main split and the inorganic ones ($N:P_2O_5:K_2O$) as sub-split to each 142 m^2 plot size within main split, replicated four times. Four inorganic fertilizer treatments consisted of full rate of 500 kg ha^{-1} N along with 0, 1/2 (125), 3/4 (188) and full (250) P_2O_5 kg ha^{-1} designated as (full N, full N+1/2 P , full N+3/4 P and full NP) in addition to two treatments i.e. full NPK (500-250-500 kg ha^{-1}) and 1.25 NP where 25% more than full NP (625-625-0 kg ha^{-1}) was applied. Inorganic fertilizer application (urea, di-ammonium phosphate and sulphate of potash) initiated in the month of March and continued all the way till November 2011, except in the month of June. Farm manure and composted pressmud were applied each at 20 t ha^{-1} in the month of December, 2010. Zinc sulphate was applied (10 kg ha^{-1}) to all the treatments only once in the month of March.

Sampling and processing: Before application of fertilizer treatments, twenty five soil samples were randomly collected from the banana experimental area at soil depth (0-30 cm) and composited. Well decomposed farm manure was collected from the vicinity of experimental site and applied to main plot (11 kg per plant) during winter season after the harvest of banana fruit. The composted pressmud was prepared by mixing 1000 kg (1 ton) of pressmud with 100 ml of boiler ash and 300 ml of spent wash. The process of composting continued (4 weeks) till the temperature of the mixture cooled down to the ambient temperature. The mixture was mixed twice to avoid excessive increase in temperature. For banana yield and nutrient composition of fruit, six plants were randomly selected. Banana bunches were harvested for one complete growth cycle from each treatment and used for calculating the yield in tons per hectare. Further, fruit samples were collected from each treatment by taking 2-3 fingers from middle hand of each harvested bunch. The removed banana fingers were rinsed with tap water to decontaminate from dust and other adherent material, thrice washed with distilled water and excess moisture was removed using tissue paper. The peeled banana fruit was cut into round slices and dried by placing the petri dishes in oven at 70°C, according to Anon. (2000). Further, the slices were cooled, ground in steel stainless Feed Grinder (Retsch Karl Kola -313) and analyzed for total N, P, K, Cu, Fe, Mn and Zn.

Table 1. Properties of soil and organic wastes.

Electrical Conductivity (dS m^{-1})	pH	$CaCO_3$ (%)	Organic matter (%)	Soil	(0-30cm)	DTPA extractable				Textural class
				Olsen P	NH_4OAc extractable K	Cu	Fe	Mn	Zn	
				(mg kg^{-1})						
0.30	7.7	11.3	0.70	11.3	143	3.7	5.9	7.3	0.30	Clay loam

Organic wastes

Organic wastes	N	P	K	Cu	Fe	Mn	Zn	C:N ratio
	---------------(%)----------------			---------------mg kg^{-1}-----------------				
Farm manure	2.07	1.30	1.31	40.2	895	464	46.8	20.8
Composted pressmud	2.15	1.76	0.83	79.4	848	341	48.5	15.2

Table 2. Effect of inorganic fertilizer application on banana nutrient composition.

Inorganic fertilizer application (N-P_2O_5-K_2O kg ha^{-1})	N	P	K	Cu	Fe	Mn	Zn
	-------------(%)--------------			---------------------mg kg^{-1}---------------------			
500-0-0 (full N)	1.21 a	0.10 d	1.07 b	1.31 a	18.5 abc	1.29 ab	1.99 c
500-125-0 (full N+1/2 P)	1.10 a	0.11 cd	1.01 b	1.36 a	17.5 abc	1.54 a	2.54 ab
500-188-0 (full N+3/4th P)	1.18 a	0.13 bc	1.02 b	1.56 a	19.7 a	1.42 ab	2.65 a
500-250-0 (full NP)	1.06 a	0.15 ab	0.99 b	1.65 a	19.2 ab	1.17 b	2.17 bc
500-250-500 (full NPK)	1.07 a	0.16 ab	1.85 a	1.41 a	16.9 bc	1.23 b	2.26 bc
625-625-0 (1.25 NP)	1.13 a	0.17 a	1.18 b	1.53 a	16.1 c	1.27 ab	1.93 c
Standard error	0.178	9.61	0.123	0.147	0.88	0.094	0.126
Least significant difference ($LSD_{0.05}$)	NS	0.028	0.366	NS	2.62	0.279	0.375

Means with the same letters are not significantly different at 0.05

Table 3. Effect of organic wastes on nutrient composition of banana fruit.

Organic application	N	P	K	Cu	Fe	Mn	Zn
	-------------(%)----------			--------------------mg kg^{-1}-----------------			
Control	0.88 b	0.11 b	0.82 b	1.49 a	13.9 b	1.29 a	2.18 a
Farm manure	1.19 a	0.12 b	1.45 a	1.52 a	19.4 a	1.41 a	2.27 a
Composted pressmud	1.31 a	0.19 a	1.29 a	1.41 a	20.6 a	1.25 a	2.31 a
Standard error	0.09	4.52	0.08	0.098	0.808	0.068	0.061
Least significant difference ($LSD_{0.05}$)	0.283	0.013	.247	0.302	2.479	NS	NS

Means with the same letters are not significantly different at 0.05

Analytical methods: Collected soil samples were analyzed for physical and chemical properties as presented in Table 1. The texture of soil was determined by hydrometer method, electrical conductivity and pH in 1:2 soil-water extracts, organic matter by Walkley Black, total N by Kjeldahl's digestion and distillation and $CaCO_3$ by acid neutralization method (Estefan *et al*., 2013). Available P in soil was extracted by 0.5M $NaHCO_3$ (pH 8.5), followed by development of blue coloured complex (Murphy & Riley, 1962) using spectrophotometer (ANA-75). Potassium was extracted in 1N NH_4OAc and quantified using emission spectroscopy (JENWAY PFP 7) (Knudsen *et al*., 1982). Whereas, micronutrients were extracted by diethylene-triamine penta-acetic acid (DTPA) method of Soltanpour & Schwab (1977), followed by their quantification by absorption spectroscopy (Perkin Elmer model Analyst 700).

Farm manure, composted pressmud and banana fruits were quantified for total N, P, K, Cu, Fe, Mn and Zn and are presented in Table 1. The composted pressmud, in addition was tested for organic matter and C:N ratio. Total N was determined by (Bremner & Mulvaney, 1982). In case of P, K, Cu, Fe, Mn and Zn determination, a 0.25 g portion of each farm manure, composted pressmud and banana fruit powder separately containing 10 ml of acid mixture ($HClO_4$:HNO_3 - 1:5) was kept overnight and digested at 80ºC (Zarcinas *et al*., 1987). The digested material was properly diluted and developed into a yellow coloured complex (Yoshida *et al*., 1976; Cottenie, 1980) using spectrophotometer. For N, K, Cu, Fe, Mn and Zn determination, same methods were used as covered under soil determination. The data were statistically analyzed in a two factor (organic wastes and inorganic fertilizer) analysis of variance using split plot design and the means were compared at $LSD^{0.05}$ using Statistix 8.1 (Anon., 2005).

Results and Discussion

The effect of inorganic fertilizer treatments and organic sources of nutrients (separately) on nutrient composition of banana fruit is presented in Tables 2-3. In case of interaction between the two (organic and inorganic nutrient sources), the data are presented in Fig. 1. The relationship between yield and nutrient composition of banana fruit is given in Fig. 2.

Nutrient composition of banana fruit: Nutrient composition of banana fruit varied with the nature of treatments. Application of inorganic fertilizers had no significant effect on N contents of banana fruit. As the N application rate was same for all the treatments, except in case of treatment receiving 25% more N (1.25 NP), there was no increase in the values. In fact, a decreasing trend was observed with the increase in P rates applied along with N (Table 2). Even though the treatment differences were non-significant, the declining trend was the sign pointing out dilution effect due to application of P and K fertilizers (full NPK). In case of P or K application of inorganic fertilizers, there was significant enhancement in the respective nutrient contents of banana fruit. Phosphorus content of the fruit increased from 0.10% (full N treatment) to maximum value of 0.17% with application of 1.25 NP. A significant increase in fruit P was also noted at sub-optimal rate of P (full N+3/4 P). The K content increased from 1.07% in full N alone treatment to 1.85 % in treatments receiving full NPK, which corresponds to 72.89% increase.

The study also evaluated the effect of these fertilizer applications on micronutrient contents (Table 2). The Cu content increased with the application of fertilizers, but the treatment differences were statistically non-significant. The fertilizer treatments although produced significant increase in other three nutrients i.e. Fe, Mn and Zn contents ranging from 16.9 (full NPK), 1.17 (full NP) and 1.99 mg kg^{-1} (Full N) to 19.7 (full N+3/4 P), 1.54 (full N+1/2 P) and 2.65 mg kg^{-1} (full N+3/4 P), respectively. However, a general decrease in these nutrients was observed in treatments receiving full NPK and 1.25 NP. The only exception was the treatment full N+1/2 P having significantly higher Mn than that of full NP and full NPK treatments. Increasing rate of P application to full NP, or addition of K (full NPK) or increasing the NP rate to 1.25 NP produced a significant decline in Zn contents termed as "dilution effect" in view of increased growth and yield of banana under the influence of fertilizer treatments.

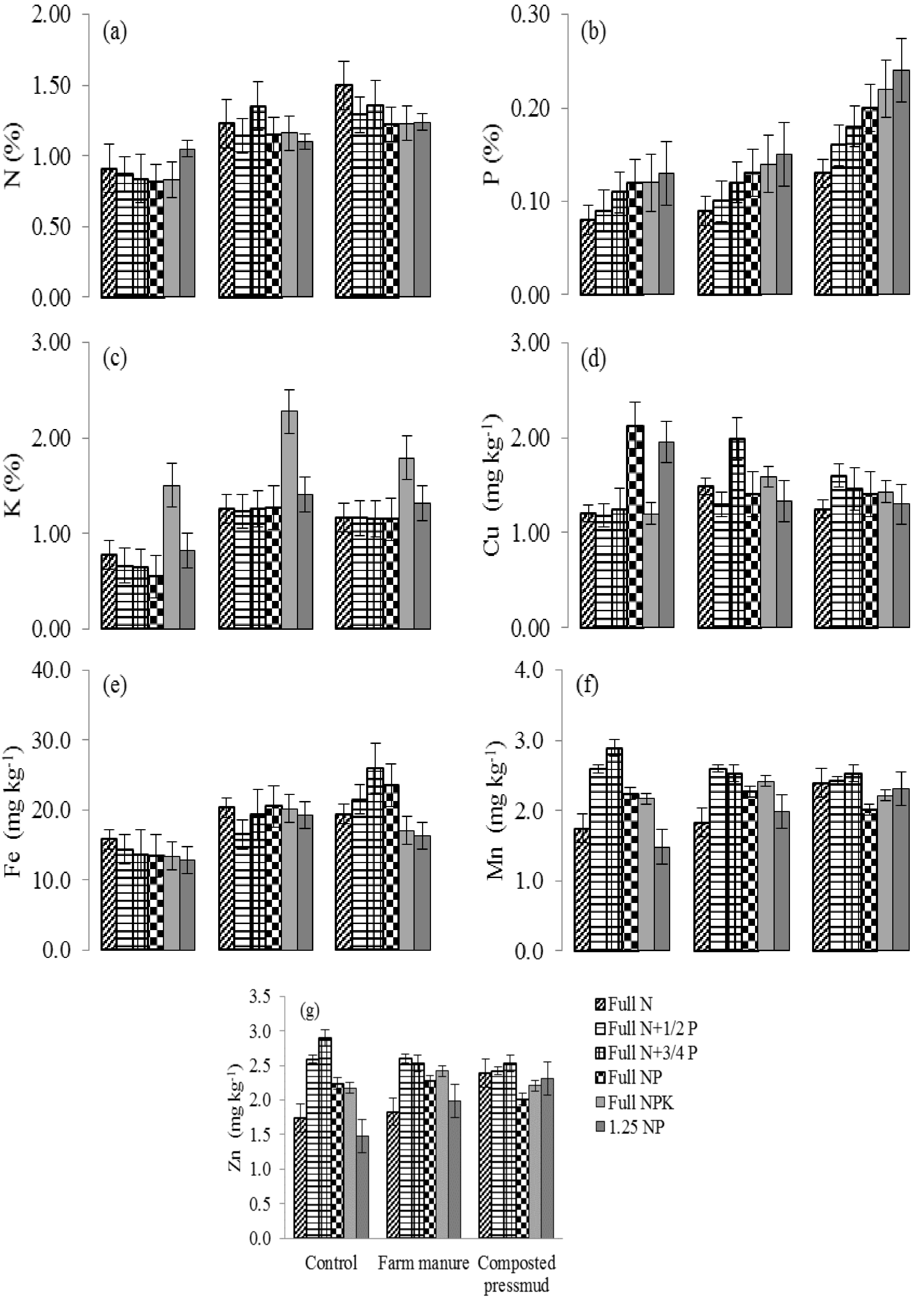

Fig. 1. Combined effect of organic wastes and inorganic fertilizers on nutrient composition of banana fruit (a) N, (b) P, (c) K, (d) Cu, (e) Fe, (f) Mn and (g) Zn

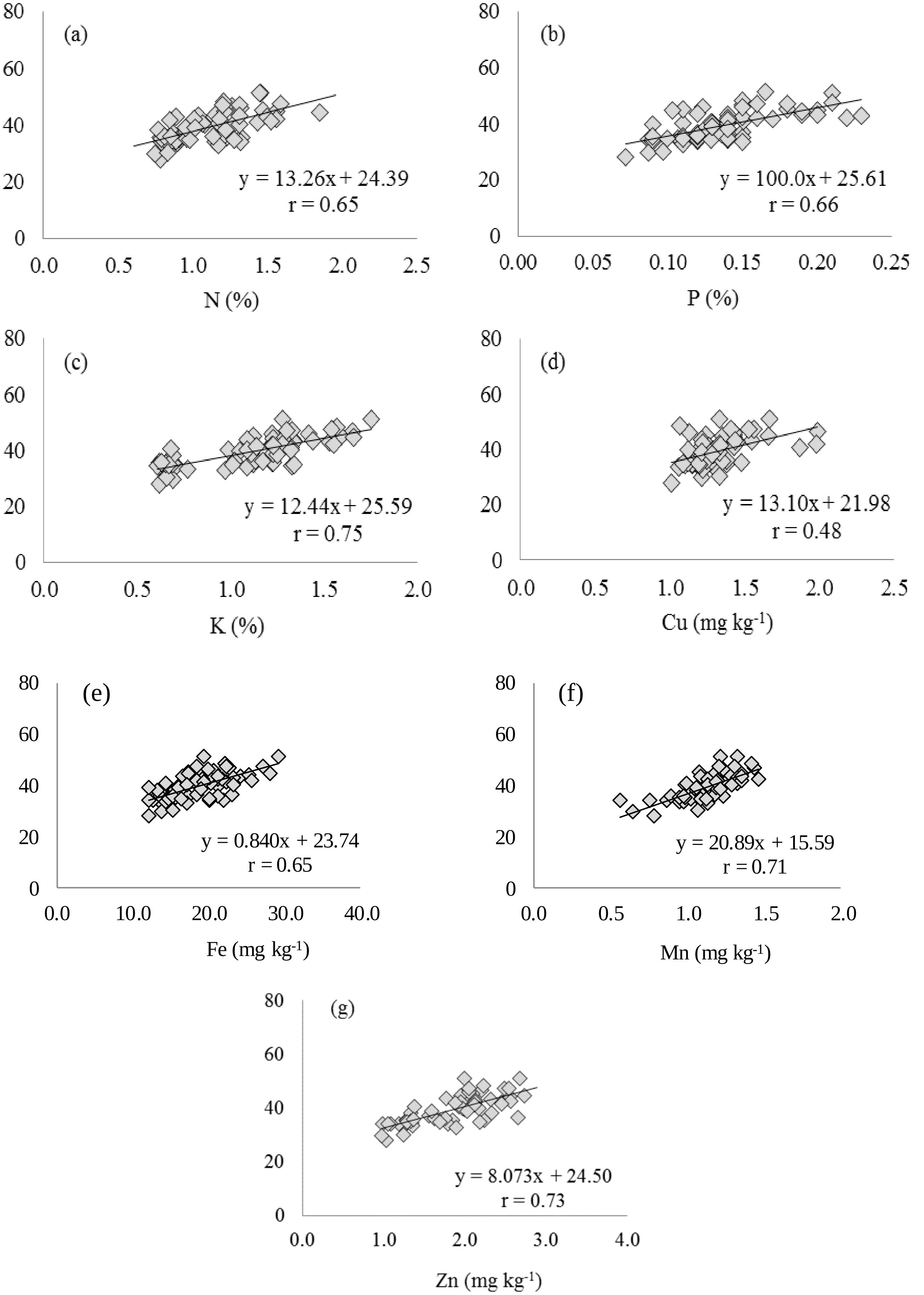

Fig. 2. Relationship between yield and nutrient composition of banana fruit (a) N, (b) P, (c) K, (d) Cu, (e) Fe, (f) Mn and (g) Zn.

Application of organic sources significantly increased N, P and K contents of the fruit and that the farm manure and composted pressmud were equally effective, with exception to P contents where composted pressmud outperformed farm manure (Table 3). This may be due to high P contents of pressmud compared to farm manure. The fruit N contents increased from 0.88 to 1.19 and 1.31%, P from 0.11 to 0.12 and 0.19% and K from 0.82 to 1.45 and 1.29% from control (full N treatment) to farm manure and composted pressmud, respectively. This amounted to 48.86% increase in fruit N, 72.7% in P and 57.31% in K content with application of composted pressmud. Statistically, the effects of farm manure and composted pressmud were similar for N and K. The application of farm manure did not increase fruit P content. The fruit contents had no improvement in Cu, Mn and Zn with the application of both farm manure and composted pressmud. However, Fe contents showed significant improvement due to organic application. The values increased from 13.9 to 19.4 and 20.6 mg kg^{-1} with application of farm manure and composted pressmud, respectively, corresponding to 48.3% increase with composted pressmud. Statistically, the effect for farm manure and composted pressmud were similar.

It was further noted that interaction between organic sources and inorganic fertilizer treatments had a significant effect on Cu, Fe and Zn (Fig. 1a-1g) contents. Increasing the P rate to full P (full NP and NPK treatments) did not produce further increase in fruit P unless higher rate of P (as in 1.25 NP treatments) was applied (Fig. 1b). The data showed that without application of P fertilizers or organic sources of nutrients, the P content of fruit was the lowest (0.08% P). Overall, the values ranged between 0.08 and 0.24%. For the treatments receiving organic sources of nutrients along with NPK, mean K contents increased to 2.28% with farm manure and 1.79% with composted pressmud (Fig. 1c). The Cu content ranged between 1.18 and 2.13% in treatments (full N+1/2 P and full NP) receiving 1/2 and full P, respectively along with full N and control (no organic source) treatments (Fig. 1d). The Fe content increased from 12.8% in 1.25 NP in control (full N) to 26% in full N+3/4 P along with composted pressmud treatment (Fig. 1e). In case of Zn, the values were between 1.48 and 2.89% in 1.25 NP and full N+3/4 P treatments, respectively both in control (full N) block where no organic source application was carried out (Fig. 1g). Increasing rates of P contributed to significant increase in Fe content for the treatments where composted pressmud was applied. When K (full NPK) or 1.25 NP was applied, the Fe contents showed significant decline.

Literature on banana nutrient composition is generally scarce and the studies concerning the effect of organic and inorganic sources of nutrients on banana nutrient management in particular. Variable nutrient contents in banana fruit have been reported by different authors. Banana fruit samples collected from local Karachi market of Pakistan had Cu, Fe, Mn and Zn contents of 1.42, 16.5, 0.037 and 0.785 mg kg^{-1}, respectively (Zahir *et al*., 2009). These results reported more or less similar contents for Cu and Fe contents, however, Mn and Zn contents were way too low than those obtained in this study which may be due to treatment differences in fertilizer and organic sources. Ndukwe *et al*. (2012) reported respective banana (Musa spp.) N, P, K, Fe and Zn contents of 0.72, 0.21, 1.41 g kg^{-1}, 18.08 and 0.93 mg kg^{-1} with N-K_2O (300-550) compared to those (0.67, 0.11, 1.44 g kg^{-1}, 19.55 and 0.80 mg kg^{-1}) with poultry manure (20 t ha^{-1}) application. The treatment differences among poultry manure and inorganic fertilizer applications were non-significant. The values obtained by inorganic fertilizer application as in this study were much higher compared to the values reported by them. This is due to proper N fertilizer application (i.e. 500 kg ha^{-1}) rate in the study against the 300 kg ha^{-1} and inclusion of P application. The results as given by Attia *et al*. (2009) showed that the combined application of 25% P_2O_5+ bio (phosphate solublizing bacteria) increased the fruit NPK (1.7, 0.124 and 2.25%) and Zn (3.37 mg kg^{-1}) compared to solo application of each. The Mn contents were more or less similar in all the treatments; however, Fe was more each in fertilizer and bio treatments. Considering the average of average inorganic fertilizers and organic sources, the nutrient composition of banana fruit was in the order of K>N>P>Fe>Zn>Cu>Mn. The order followed by Wall (2006) for Hawaiian banana was more or less similar except in case of Mn which was more than other three micronutrients.

Relationship between yield and nutrient composition of banana fruit yield component was not the main parameter of this study; however, to highlight the importance of nutrient composition in relation to yield, banana yield was regressed against nutrient contents in fruit to determine the nature of their relationship as indicated in Fig. 2. The relationship was linear, positive and significant ($p<0.01$) for all the nutrients i.e. N, P, K, Cu, Fe, Mn, and Zn. No studies so far have developed regression equations concerning nutrient composition of banana fruit related to yield as this study. The literature available on banana mostly report relationship pertaining to leaf tissue nutrients and growth parameters as those reported by Murray, 1960 and García *et al*., 1977. They reported positive correlations between K content in leaf tissue and bunch weight and number of hands per bunch. Alvarez *et al*. (2001) found no correlations among yield, growth parameters, leaf tissue and fruit contents for banana cultivar Gruesa Palmera, an improved clone of the cultivar Dwarf Cavendish. The basic reason for poor or no relationship in their study was low spreading of the experimental data.

Conclusion

The outcome of this study illustrated relative benefit of combined application of inorganic fertilizers (NPK) and organic sources of nutrients over their separate utilization. All the nutrients of banana fruit had minimum values at N alone treatment. In case of banana fruit nutrient composition, the inorganic fertilizer application (full NPK) increased P and K contents by 50 and 95% over N alone treatment except in case of N. Addition of farm manure and composted pressmud increased all three nutrients (NPK) by 27.5 and 35.2, 75.0 and 175.0, and 196.1 and 132.5%, respectively over N alone treatment. Application of inorganic fertilizers alone had no effect on micronutrient contents except in case of Zn which increased by 24.7%. A significant percent increase in Cu (32.5 and 19.2), Fe (27.9 and 8.2) and Zn contents (39.1 and 27.0) was recorded with addition of farm manure and composted pressmud respectively. A general decline in Fe, Mn and Zn contents with higher rates of inorganic fertilizer application (i.e. full NPK and 1.25 NP) was observed due to dilution effect. A positive, linear and significant ($p<0.01$) relationship was observed between yield and banana fruit nutrients i.e. N, P, K, Cu, Fe, Mn, and Zn. The P requirement was similar with and without application of organic sources of nutrients. Through this study it is inferred that banana yields can further be increased at higher NP rates (1.25NP) by including graded rates of K fertilizer which needs to be explored.

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