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Integrated Application of Poultry Manure and Chemical Fertiliser on Soil Chemical Properties and Nutrient Uptake of Maize and Soybean

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ABSTRACT

Low soil fertility due to monoculture cereal production systems and inadequate fertiliser application are some of the major causes for declining crop production in developing countries. Integrated use of organic and inorganic fertilisers is an option to alleviate soil fertility problem as it utilises available organic and inorganic nutrients for sustainable agricultural production and productivity. A field experiment was conducted in 2014 at Universiti Putra Malaysia to evaluate the effect of the integrated application of poultry manure and inorganic fertiliser on soil chemical properties and nutrient uptake of maize and soybean in maize-soybean intercropping. Treatments comprised combinations of three cropping systems (sole maize, sole soybean, and maize + soybean) and four fertilisation regimes (control, 100% NPK, 100% poultry manure (PM) and 50% NPK + 50% PM). The experiment was laid out in a randomised complete block design (RCBD) with three replications. Results showed that either growing soybean alone or as an intercrop with maize resulted in increased soil organic matter (OM) ($P<0.05$), total N ($P<0.0001$), soil available P ($P<0.0001$) and soil cation exchange capacity (CEC)($P<0.05$). Intercropping maize with soybean significantly reduced N, P and K uptake of soybean ($P<0.0001$), but uptake of N, P and K by maize was not significantly ($P>0.05$) affected by intercropping. Application of 100% PM and integrated application of 50% NPK+50% PM gave significantly higher soil pH ($P<0.001$), soil OM ($P<0.0001$), soil total N($P<0.0001$), soil available P ($P<0.0001$), soil exchangeable K ($P<0.001$) and soil CEC($P<0.0001$) compared to control and 100% NPK. For both maize and soybeans, the highest uptake of N, P and K was observed from the integrated application of 50% NPK+50% PM ($P<0.0001$). It can be concluded that integrated application of organic and inorganic fertiliser is the best option to improve soil chemical properties and nutrient uptake of maize and soybean.

Keywords: Intercropping, chemical fertiliser, NPK, poultry manure, soil chemical properties.

INTRODUCTION

Low soil fertility due to monoculture cereal production systems, inadequate fertiliszer application, biomass removal, soil erosion, nutrient losses through runoff and leaching are recognised as some of the major causes for declining

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crop production in developing countries (Negassa *et al*. 2007). Application of inorganic fertilisers is considered the most efficient way to reverse soil nutrient depletion and improve crop production (Bationo *et al.*, 2007). However, the use of inorganic fertilisers in developing countries is insignificant as most of the smallholder farmers cannot afford even a single bag to apply to their crops (Tesfa *et al*., 2001). Continuous use of chemical fertilisers in intensive cropping systems leads to increased soil acidity and nutrient imbalance which adversely affects soil health due to their susceptibility to losses through gaseous form and by leaching (Amoah *et al.*, 2012). These effects can be alleviated through the use of organic fertilisers which can improve soil physical and chemical properties. Palm *et al.* (1997) reported that organic manure improved organic matter and soil nutrient availability (N, P and K) through the total nutrients added by controlling net mineralisation-immobilisation patterns. Poultry manure is considered as one of the best organic manures as it contains both macro-and micronutrients (Dekisissa *et al.*, 2008). However, application of organic manure alone to sustain soil and crop productivity is inadequate due to their relatively low nutrient content and slow release of nutrients (Negassa *et al*., 2007).

Hence, neither the chemical fertilisers nor the organic sources can exclusively achieve the sustainable productivity of soils as well as crops under highly intensive cropping systems. To achieve sustainability of soil fertility and crop productivity, integrated use of organic manures and inorganic fertilisers together with other fertilisation practices like intercropping with legumes are very important. Integrated use of poultry manure and inorganic fertiliszer was has been shown to improve soil pH, organic matter content, cation exchange capacity and soil N, P, and K status (Amusan *et al.*, 2011).

Maize (*Zea mays* L) and soybean (*Glycine max* L. Merril) are important cereal and legume crops in the world respectively. Maize has high yield potential compared to any other cereal crops and therefore has a high requirement for nutrients, especially nitrogen (N), phosphorus (P) and potassium (K). Soybean (*Glycine max* L. Merril) has a capability of supplying nitrogen for its growth and component cereals through symbiotic nitrogen fixation, thus reducing the requirement for costly and environmentally polluting nitrogen fertilisers (Zerihun *et al.*, 2013). Maize takes up high amounts of N, P and K from the soil, while soybean derives a significant part of its N uptake from biological nitrogen fixation and P and K uptake from the soil (Roy *et al*., 2006). Therefore, it is important to ensure that the overall supply of soil N, P and K is sufficient for high yields (Roy *et al.*, 2006). An integrated application of organic and inorganic fertilisers appears to be an ideal method to meet nutrient requirements of crops rather than a sole application of either source. The synergistic effect of organic and inorganic sources on mineralisation and continued supply of essential nutrients improved soil chemical properties and uptake of nutrients, thus enhancing crop yield (Adeniyan and Ojeniyi, 2005). Therefore, this study was aimed to evaluate the effects of integrated application of poultry manure and inorganic fertiliszer on soil chemical properties and nutrient uptake of maize and soybean in maize-soybean intercropping.

MATERIALS AND METHODS

Site Description

An experiment was conducted at Field 2, Universiti Putra Malaysia (UPM) Serdang, Selangor, Malaysia (latitude 3: 02' N, longitude of 101: 42' E and altitude 31 m above sea level. Total annual rainfall in the year 2014 was approximately 1623.5 mm. Mean annual minimum and maximum temperatures were 24.5°C and 32.2°C, respectively, while the mean relative humidity was 78.9%.

The experimental soil was classified as Bungor series (Typic Paleudult) according to USDA soil taxonomy. Data on initial physico-chemical properties of soil at the experimental site are presented in Table 1. The data indicated that the soils were sandy loam, slightly acidic, low in organic matter (OM), total nitrogen (N), available phosphorus (P), cation exchange capacity (CEC) and exchangeable potassium (K).

TABLE 1

Initial chemical properties of the soil used in the experiment

Initial chemical properties of the soil used in the experiment (n=3)

Soil Properties		**Value (± S.E)**
pH		5.62 ± 0.19
Total N(%)		0.08 ± 0.01
Available P (mg kg^{-1})		16.0 ± 1.95
K($cmol_c kg^{-1}$)		0.33 ± 0.12
CEC($cmol_c kg^{-1}$)		14.5 ± 0.37
OM(%)		2.2 ± 0.32
Texture		Sandy loam
	Clay (%)	18.98
	Sand (%)	65.73
	Silt (%)	15.29

CEC = Cation Exchange Capacity, OM= organic matter, S.E= standard error

Experimental Design and Treatments

The experimental design was a three by four factorial combinations of cropping systems (sole maize, sole soybean, and combination of maize + soybean), and fertilisation (control, 100% NPK, 50% NPK + 50% poultry manure (PM) and 100% PM), laid out in Randomiszed Complete Block Design (RCBD) with three replications. A plot size of 3.6 m x 3 m was used for all treatments. The sole maize and soybean were seeded in six rows spaced 60 cm between rows in the monoculture plots. Maize and soybean were intercropped in 1:1 alternate row, i.e. 60 cm row spaced between maize crop and soybean was planted between two rows of maize crops. The spacing between plants for maize was 25 cm and for soybean was 15 cm.

The amount of PM was based on N equivalent and applied on a dry weight basis two weeks before planting.The amounts of PM in sole maize and intercropping plot were 3 t ha^{-1} and in sole soybean plot, it was 0.4 t ha^{-1}. The 50% PM treatment received half the rate of the PM treatment. The chemical composition of PM is presented in Table 2. The rates of $N:P_2O_5:K_2O$ for 100% NPK treatment were, 120:60:40 kg ha^{-1} ($N:P_2O_5:K_2O$) and 20:60:40 kg ha^{-1} ($N:P_2O_5:K_2O$) for maize and soybean, respectively. The intercropped plots receivedthe recommended fertiliszer rate of maize ($N:P_2O_5:K_2O$ at 120:60:40 kg ha^{-1}). The full dose of P and K and one-third of N fertiliszer were applied at planting time. The remaining two-thirds of N fertiliszer was applied at the 8-leaf stage of maize, while for soybean plots, the entire dose of NPK was applied at planting. All other agronomic practices were kept uniform for all treatments.

Soil Sampling and Chemical Analysis

Composite initial soil samples at a depth of 0-30 cm were taken from ten random spots within the experimental site prior to treatment application and after harvest from each plot. The composite samples were air-dried, sieved to pass through a 2-mm mesh and analysed for selected physico-chemical properties, including texture (percentage of sand, silt, and clay), pH, total nitrogen, organic matter content, available phosphorus, exchangeable K and cation exchange capacity (CEC).

TABLE 2:
Chemical composition of the poultry manure (PM) used

Nutrient Element	**Percent content**
pH	7.10
N	4.50
P	1.08
K	1.66
Ca	1.43
Mg	0.60

The soil organic carbon content, total nitrogen and sulfur were determined by dry combustion with CHNS LECO analyszer (Jimenez and Ladho, 1993). Soil pH was determined using the glass electrode pH meter in a 1:2.5 soil to water ratio (Van Reeuwijk, 1992), and CEC was measured by ammonium acetate method (NH_4OAC) by saturating the soil with 1N NH_4OAC and displacing it with 1N K_2SO_4 (Chapman, 1965). Exchangeable K was extracted with 1N NH_4OAc at pH 7 and the extract was read using an atomic absorption Spectrophotometer (Perkin-Elmer, Massachusetts, USA). Available phosphorus was determined by the Bray-II method (Bray and Kurtz, 1945) and determined by an auto-analyzer (Lachat instrument, WI, USA). Soil texture was determined by the pipette method (Day, 1965). The texture class was determined using the United States Department of Agriculture (USDA) soil textural triangle.

Plant Sampling and Chemical Analysis

At harvest, maize and soybean plants were sampled for nutrient analysis. Five plants were sampled from the middle rows of each plot. The plant samples were oven-dried at 70 ^{0}C for 72 hours and dry weight was recorded. The grain and stover samples were grinded separately to pass through a 1mm sieve in a Thomas-Wiley laboratory Mill (Thomas Scientific, Swedesboro, NJ). The ground materials were digested in H_2SO_4 and H_2O_2 using a Seal Digestion Block (Foss Tecator, Hilleroed, Denmark) at a temperature of 285 ^{0}C in accordance with the method described by AOAC (1995). The N and P contents in the digested samples were determined using an autoanalyser (Lachat instrument, WI, USA) and K content was determined using an atomic absorption spectrophotometer (Perkin Elmer, Massachusetts, USA).

After the determination of leaf, stem and grain N, P and K contents, uptake of N, P, and K amounts were calculated (Sharma *et al*., 2012).

$$\text{N,P,or K uptake (kg ha}^{-1}\text{)} = \frac{\text{N or P or K content (\%) x dry matter (kg/ha)}}{100}$$

Total N, P or K uptake (kg ha^{-1}) = Leaf N, P or K uptake + Stem N, P or K uptake + Grain N, P or K uptake.

Statistical Analysis

Data were analysed using the analysis of variance (ANOVA) procedure using SAS version 9.3. Least Significance Difference (LSD) at 95% of significance level was used for mean separation determination. Pearson correlation was used to assess relationships between nutrient uptake of maize and soybean and chemical properties of the soil.

RESULTS AND DISCUSSION

Soil Chemical Properties

Soil pH, soil organic matter, soil total N, soil available P, soil exchangeable K and soil CEC were significantly affected (P>0.0001) by fertilisation after harvest. Soil OM (P<0.05), soil total N (P<0.001), soil available P (P<0.001), and soil CEC (P<0.05) were significantly affected by cropping system. However, soil pH and soil exchangeable K were not significantly(P>0.05) affected by cropping system (Table 3). An interaction effect was observed between cropping system and fertilisation of the soil CEC(P<0.0001) (Table 4).

Application of 100% PM and 50 % NPK + 50% PM resulted in soil pH increasing from 5.40 to 6.82 and 6.63 in 100% PM and 50% NPK + 50% PM treatment, respectively. Inorganic treatment (100% NPK) showed similar pH with control (Table 3). The higher Ca content of the PM may be responsible for the increase in soil pH (Table 2). In addition, decomposition of organic manure added

TABLE 3

Effect of cropping system and fertilisation on soil chemical properties, including soil pH, organic matter (OM), total N, available P, exchangeable K, Ca, Mg and cation exchange capacity (CEC)

Treatment	**pH**	**OM** (%)	**TN** (%)	**Av. P** (mg kg^{-1})	**Ex. K**($cmol_c kg^{-1}$)	**Ca** (mg kg^{-1})	**Mg** ($mgkg^{-1}$)	**CEC** ($cmol_c kg^{-1}$)
Cropping system (C)								
Sole Maize	6.31a	2.13b	0.13b	21.2b	0.31a	2.76a	0.86a	15.9b
Sole Soybean	6.32a	2.56a	0.22a	22.4b	0.32a	3.12a	0.77ab	17.9a
Intercropping	6.21a	2.57a	0.17ab	26.3a	0.35a	2.80a	0.74b	17.7a
$LSD_{0.05}$	0.39^{ns}	0.19	0.05	4.05	0.07^{ns}	0.12^{ns}	0.12	1.29
P-value	0.91	0.03	<0.0001	<0.0001	0.24	0.47	0.04	0.007
Fertiliszation (F)								
Control	5.40b	2.13b	0.11c	15.6c	0.26b	2.20c	0.65c	12.9d
100% NPK	5.81b	2.19b	0.14c	18.5c	0.30b	2.02c	0.72c	14.7c
100% PM	6.82a	2.96a	0.24a	36.0a	0.36a	5.12a	1.02a	22.7a
50% NPK+ 50% PM	6.63a	2.74a	0.17b	25.7b	0.39a	3.15b	0.86b	18.4b
$LSD_{0.05}$	0.41	0.22	0.04	4.49	0.50	0.76	0.15	1.5
p-value	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	0.007	0.01	<0.0001
C*F	0.83^{ns}	0.07^{ns}	0.95^{ns}	0.62^{ns}	0.06^{ns}	0.97^{ns}	0.08^{ns}	<0.001
CV (%)	7.1	18.8	21.3	9.00	21.2	26	18	8.9

Means followed by the same letter in the same column are not significantly different ($LSD_{0.05}$), ns = non-significant at α=0.05, CV (%) = coefficient of variation, Av. P= available P, EX. K= exchangeable K basic plant nutrients to the soil that contributed to the increase of in soil pH. This result is in agreement with Islam *et al*. (2013) who reported that the application of PM raised the pH of the soil.

Significantly higher ($P<0.05$) OM was observed in intercropping and sole soybean treatment than in the sole maize treatment (Table 3). Ali *et al*. (2015) found higher soil OM in sole soybean treatment than in sole maize. In addition, Matusso *et al*. (2014) reported that soil OM in intercropping treatment was higher than in sole maize treatment. Among fertilisation treatments, soil OM was significantly higher ($P<0.0001$) in the 100% PM and 50% NPK + 50% PM treatments than in sole 100% NPK and control treatment. An increase in soil OM in the PM treatment may be due to the effects of manure, which act as the storehouse of different plant nutrients. Zhao *et al*. (2009) reported that the application of organic manure singly or in combination with inorganic fertiliszer resulted in higher OM content than the exclusive application of chemical fertilisers (NPK).

Significantly higher soil N was observed in sole soybean treatment than in the sole maize treatment (Table 3). In which ever plot soybean crop was grown, total N was significantly higher ($P<0.001$) compared to maize crop. The increase in the total nitrogen was probably due to the ability of the soybean to fix atmospheric N in the soil through symbiotic N fixation. Matusso et al. (2014) reported that mineral N was significantly affected by the intercropping treatment and the highest N was observed from a sole soybean treatment.

Regarding fertilisation treatments, total N was significantly higher in the 100% PM and 50% NPK + 50% PM treatment than in 100% NPK and control treatment ($P<0.001$). Application of 100% NPK and control treatment were not significantly different between each other in soil total N. This may be due to the N from inorganic fertiliszer being rapidly used up by the plant or could have leached (Masaka *et al.*, 2015). This finding is in agreement with Datt *et al*. (2013) who observed low N in the inorganic fertiliszer treatment. The high total N in PM treatment was due to the slow release of N during mineralisation of PM. Similarly, higher total N in integrated treatments may be due to the fact that integration of organic and chemical fertilisers increased the mineralisation owing to the narrow C/N ratio. This result is in agreement with Ayeni and Adetunji (2010) who reported PM and their combinations with NPK fertiliszer increased soil OM, N, P and K in soil.

Available P increased from 21.2 and 22.4mg/kg in mono crop of maize and soybean respectively, to 26.3mg/kg in intercropping which may be due to more efficient utilisation of plant nutrients in intercropping than in mono cropping (Miyazawa *et al*., 2010). As there is a synergistic relation of N with P, K, and S, this might have helped in increasing the soil available P in sole soybean treatment than in sole maize treatment (Vidyavathi *et al.*, 2012b). The result is supported by Khan et al. (2014) who found that intercropping can increase soil available nutrients and improve soil fertility compared to sole cropping. Application of 100% PM resulted in available P that was significantly higher than in control and 50% PM + 50% NPK treatments ($P<0.0001$). The combined application of inorganic fertilizser and PM gave higher soil P concentration compared to the control and 100% NPK fertiliszer treatments. An increase in soil available P in 100% PM treatments may be due to mineralisation of organic P and production of organic acids that makes soil P more available and reduces P fixation. This result corroborates the findings of Islam *et al*. (2013), who explained that soils treated with either organic fertilisers or, inorganic fertilisers or combination of these fertilisers, higher values of available P will be obtained compared to the control treatments. Boateng et al. (2006) also reported that the application of PM increased soil available P by 31% compared to the control treatment.

Exchangeable K was significantly higher in 100% PM and 50% NPK+50% PM treatments than control treatment (P<0.0001). The increase in soil exchangeable K in a combined application of inorganic and organic fertiliszer treatments may be due to the direct of potassium addition in the soil K pool. This result is supported by Islam *et al*. (2013) who reported that soil exchangeable K increased when organic or both organic and chemical fertilisers were applied. Ahmad *et al*. (2013) also reported that the highest soil OM, total N, available P and exchangeable K, after maize was harvested, was from treatments receiving organic sources with 50% of recommended NPK fertilisers.

In the sole maize cropping system, soil CEC under application of 100% PM was not significantly different (P>0.05) from combined application of 50% NPK + 50% PM (Table 4). However, in sole soybean and maize + soybean intercropping system, soil CEC under application of 100% PM was significantly higher (P<0.0001) than in combined application of 50% NPK + 50% PM. The increase in soil CEC with PM application was due to the addition of basic cations in the soil such as K, Mg and Ca from the decomposition of poultry manure (Table 3). Adekayode and Ogunkoyaka (2011) reported higher soil total N, available P, exchangeable K and CEC in organic compost treatments compared to NPK fertiliszer treatments.

TABLE 4
Interaction effects of cropping systems and fertilisation on soil cation exchange capacity (CEC)

Fertiliszation	CEC ($cmol_c kg^{-1}$) Cropping system		
	Sole Maize	**Sole Soybean**	**Maize + Soybean**
Control	12.8b	12.8c	13.1c
100% NPK	13 8b	13.8c	13.6c
100% PM	18.2a	26.3a	23.7a
50% NPK+50% PM	16.6a	18.8b	20.3b
$LSD_{0.05}$	2.67	2.95	2.06
p-value	<0.0001	<0.0001	<0.0001

Means followed by the same letter in the same column are not significantly different($LSD_{0.05}$)

Further, the increased soil CEC in sole soybean treatment compared to sole maize treatment was associated with a rise in soil organic matter content in sole soybean treatments (Table 4). Bronick and Lal (2005) reported the positive effect of legume intercropping on soil CEC.

Nutrient Uptake of Maize and Soybean

Uptake of N, P and K of soybean was not significantly affected by cropping system (P>0.05) (Table 6). However, N, P and K uptake by soybean wasreduced (P<0.0001) when intercropped with maize compared to monocropped soybean (Table 5) (Author: Table 5 should be cited before Table 6) . The reduction of N uptake of soybean in an intercropping treatment may be due to the shading effect of the tall maize that limited photosynthetic assimilation of soybean which thereby indirectly influenced the process of nodulation or N fixation and (Table 6) N uptake. P and K uptake of soybean was reduced due to the more competitive ability of maize with respect to the uptake of nutrients from the rhizosphere, as maize had a greater root length than soybean. The result is in line with Matusso *et al.* (2013) who reported that N, P and K uptake by soybean was significantly higher in monocropping than intercropping. Similarly, Prajapat *et al*. (2015) reported that the cropping system adopted had a significant effect on N, P, and K, uptake of soybean.

Among fertilisation treatments, the highest uptake of N, P and K by maize and soybean werewas recorded in the application of 50% NPK + 50%PM (P<0.0001) followed by sole application of 100% PM and 100% NPK (Table 5). In contrast, the control treatments had the lowest N, P, and K uptake. An increase in nutrient uptake in a combination of NPK and PM may be due to the increase in supply of NPK directly through the organic and inorganic source to the crop, the reduction in losses of nutrient from the soil solution and the increase in nutrient use efficiency (Dubey *et al*., 2012). Therefore, the high nutrient uptake in combined application of 50% NPK + 50% PM treatment is attributed to the relative availability of N, P and K throughout the cropping seasons as the nutrients from inorganic sources were available to the crop in the early stages; in the later stages of crop growth, the slow and continuous release of nutrients from the organic source became available. Moreover, the highest N uptake of soybean in combined application of organic and inorganic fertiliser might be due to increased nodulation (Table 6). The result is in line with Tagoe *et al*. (2008) and Verde *et al*. (2013) who observed higher N, P, and K uptake by soybean under application of organic manure and in combination with inorganic fertiliser. Similarly, Shashidhar *et al*. (2009) and Vidyavathi *et al.* (2012a) reported that integrated fertilisation practices give significantly higher uptake of N, P and K by maize when compared to the sole application of inorganic and organic fertilisers.

TABLE 5:
Effect of cropping system and fertilisation on nutrient uptake of maize and soybean

Treatment	N uptake (kgha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})
Sole maize	51.0a	10.5a	23.6a	_	_	_
Sole soybean	_	_	_	52.5a	38.1a	46.9a
Maize + soybean	47.8a	10.4a	21.1a	38.5b	23.9b	33.4b
$LSD_{0.05}$	5.4^{ns}	1.78^{ns}	3.2^{ns}	3.8	6.6	3.7
p-value	0.78	0.31	0.76	<0.0001	<0.0001	<0.0001
Fertilisation (F)						
Control	27.2c	3.61c	12.2c	21.5c	8.6c	17.9c
100% NPK	49.1b	10.5b	24.8b	49.8b	33.3b	43.1b
100% PM	51.4b	11.2b	22.3b	49.9b	37.4b	45.3b
50 % NPK+ 50% PM	70.0a	16.5a	30.1a	60.7a	49.4a	54.4a
$LSD_{0.05}$	7.64	2.52	4.5	5.4	8.6	5.3
p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
C*F	0.35^{ns}	0.38^{ns}	0.20^{ns}	0.57^{ns}	014^{ns}	0.12^{ns}
CV (%)	12.49	19.41	16.4	9.5	20.1	10.6

Means in the same column followed by the same letters are not significantly different ($LSD_{0.05}$), ns= non-significant, ns = non-significant at α=0.05,CV (%) = coefficient of variation

TABLE 6
Effect of cropping system and nutrient management on number of nodules and photosynthesis rate of soybean

Treatment	Photosynthetic rate (μmolm^{-2} s^{-1})	No. Nodules/plant
Cropping system (C)		
Sole soybean	22.2a	48.6a
Maize +soybean	18.9b	34.7b
LSD (p<0.05)	1.53	4.7
p-value	<0.0001	<0.0001
Nutrient Management (N)		
Control	15.3c	28.7d
100% NPK	21.8ab	37.5c
100% PM	20.2b	44.4b
50 % NPK+ 50% PM	23.2a	56.0a
LSD (p<0.05)	1.81	6.68
p-value	<0.0001	<0.0001
C*N	0.32^{ns}	0.51^{ns}

Application of sole NPK and PM increased the nutrient uptake over control, which implies that the application of NPK and PM either separately or in combination improves the availability of N, P and K to the maize and soybean. This may be due to the addition of organic manure which improved the soil properties, hence, enhancing N, P and K uptake. The chemical properties of soil were positively correlated with N, P and K uptake of maize (Table 7) and soybean (Table 8). This result is in agreement with Vidyavathi *et al.* (2012b) who reported increased nutrient uptake as soil properties improved. Moreover, the organic fertiliszer might have supplied other nutrients which enhanced N, P and K uptake (Verma *et al.*, 2006).

TABLE 7

Pearson linear correlation coefficients between N, P and K uptake of maize and soil chemical properties

	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})	pH	OM (%)	TN (%)	Av. P (mg kg^{-1})	Ex K(cmol$_c$ kg^{-1})	CEC (cmol$_c$ kg^{-1})
N uptake (kg ha^{-1})	1								
P uptake (kg ha^{-1})	0.99** (0.001)	1							
K uptake (kg ha^{-1})	0.97* (0.002)	0.97* (0.02)	1						
pH	0.79 (0.20)	0.79 (0.21)	0.69 (0.30)	1					
OM (%)	0.66 (0.30)	0.66 (0.33)	0.52 (0.47)	0.98* (0.02)	1				
TN (%)	0.51 (0.49)	0.52 (0.48)	0.42 (0.57)	0.91 (0.08)	0.93 (0.06)	1			
AV. P (mg kg^{-1})	0.52 (0.48)	0.53 (0.46)	0.41 (0.58)	0.93* (0.05)	0.96* (0.03)	0.99* (0.006)	1		
EX. K (cmol$_c$kg^{-1})	0.93 (0.07)	0.93 (0.07)	0.83 (0.16)	0.95* (0.26)	0.88 (0.11)	0.73 (0.29)	0.77 (0.24)	1	
CEC (cmol$_c$kg^{-1})	0.58 (0.42)	0.59 (0.40)	0.48 (0.52)	0.95* (0.04)	0.97* (0.02)	0.99* (0.009)	0.99* (0.002)	0.80* (0.01)	1

Value within brackets is p-value, *,** significant level of $p< 0.05$ and $p<0.01$, TN= Total Nitrogen, AV. P= available phosporous, Ex. K = exchangeable potassium

TABLE 8
Pearson linear correlation coefficients between N, P and K uptake of soybean and soil chemical properties

	N uptake (kg ha-1)	P uptake (kg ha-1)	K uptake (kg ha-1)	pH	OM (%)	TN (%)	Av. P (mg kg-1)	Ex K(cmolck g-1)	CEC (cmolc kg-1)
N uptake (kg ha-1)	1								
P uptake (kg ha-1)	0.99** (0.0005)	1							
K uptake (kg ha-1)	0.99* (0.02)	0.99* (0.02)	1						
pH	0.79 (0.20)	0.84 (0.20)	0.82 (0.31)	1					
OM (%)	0.64 (0.34)	0.71 (0.33)	0.68 (0.48)	0.98* (0.02)	1				
TN (%)	0.58 (0.49)	0.61 (0.46)	0.62 (0.58)	0.91 (0.08)	0.93 (0.06)	1			
AV. P (mg kg-1)	0.56 (0.48)	0.61 (0.47)	0.60 (0.59)	0.93 (0.07)	0.96* (0.03)	0.99* (0.006)	1		
EX. K (cmolckg-1)	0.88 (0.07)	0.93 (0.07)	0.90 (0.16)	0.95* (0.05)	0.88 (0.11)	0.73 (0.27)	0.76 (0.26)	1	
CEC (cmolckg-1)	0.62 (0.42)	0.66 (0.40)	0.66 (0.52)	0.95* (0.04)	0.97* (0.002)	0.99* (0.009))	0.99* (0.002)	0.80* 0.05	1

Value in the brackets is p–value, ***,**** significant level of p< 0.05 and p<0.01, TN= Total Nitrogen, AV. P= available phosporous, Ex.K = exchangeable potassium

CONCLUSIONS

Application of 50% NPK + 50% PM and 100% PM improved soil chemical properties and nutrient uptake of maize and soybean. Soil OM, total N, available P and CEC were high in sole soybean and intercropping with maize. Intercropping reduced nutrient uptake of soybean but had no significant effect on nutrient uptake of maize. Therefore an integrated soil fertility management, specifically, the combined application of PM with inorganic fertiliszer and intercropping soybean with maize can increase pH, OM, and soil nutrient availability in comparison with monocropped maize with 100% inorganic fertiliser. In addition this practice can result in a reduced cost of production.

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