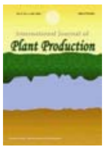

International Journal of Plant Production 7 (2), April 2013
ISSN: 1735-6814 (Print), 1735-8043 (Online)
www.ijpp.info

GUASNR

Maize production, economics and soil productivity under different organic source of nutrients in eastern himalayan region, India

V.K. Choudhary[a,*], P. Suresh Kumar[b]

[a]*ICAR Research Complex for NEH Region, Arunachal Pradesh Centre, Basar, India-791 101.*
[b]*Central Tuber Crops Research Institute, Thiruvananthpurum, Kerala, India-695 017.*
*Corresponding author. E-mail: ind_vc@rediffmail.com

Received 26 January 2012; Accepted after revision 20 November 2012; Published online 1 February 2013

Abstract

Replenishing nutrients through organic sources is essential to maintain the soil health and sustainability in Eastern Himalayan Region, India which is organic by default. Keeping this in mind an experiment was laid out on randomized block design with six treatments *viz.,* T_1: Vermicompost (VC; 2.5 Mg ha^{-1}), T_2: Poultry manure (PM; 1.25 Mg ha^{-1}), T_3: Swine manure (SM; 3.0 Mg ha^{-1}), T_4: Cow dung manure (CDM; 10.0 Mg ha^{-1}), T_5: Farm yard manure (FYM; 10.0 Mg ha^{-1}) and T_6: control and replicated thrice to study the effect of applied organic nutrients on growth and yield attributes of maize. The physical parameters like porosity, maximum water holding capacity (MWHC), field capacity (FC), permanent wilting point (PWP), bulk density (BD) and moisture releasing pattern was measured better when the crop was supplied with FYM followed by CDM. Chemical parameters like pH, Soil organic carbon (SOC), available nitrogen (N), phosphorus (P) and potassium (K) were recorded better on VC followed by PM over control. The growth, physiological parameters, yield attributes and yield were recorded higher on VC. The uptake of nitrogen, phosphorus and potassium was higher on VC followed by PM, whereas least nutrients were taken up by control. Similarly the gross and net return was recorded higher on VC followed by PM, whereas, B: C ratio was recorded higher on PM followed by CDM. However the lowest economic returns were recorded on control. Agronomic efficiency was recorded higher on VC followed by PM.

Keywords: Maize; Organic sources; Growth; Yield; Economics; Soil properties.

Introduction

India population demands 300 MT of food grain by 2025, which likely impose serious threat to food security. Maize (*Zea mays* L.) “Queen of cereals” is the third most important cereal crop in the world after wheat and rice with respect to area and productivity. It has a great significance as human food, animal feed and diversified uses for large number of industrial products. The productivity of maize mainly depends on its nutrient management. In Arunachal Pradesh, it is grown in an area of 48.1 thousand hectares with annual production of 76 thousand metric tones (DoA, 2008-09). Throughout the world, genuine concern exists over the increased use of fertilizer and pesticides in agriculture as they cause greater public health and environmental problems. Rapid change in minimum and maximum temperature, causes greater vegetative impact on soil organic carbon which not only the source of nutrients but also important for the population of many beneficial microbes. Therefore, maintaining the optimum organic carbon is very much required. Long term field experiments have clearly visualized the negative impact of continuous use of chemical fertilizers on soil health (Yadav, 2003). There is need to adopt practices, which can improve the soil health and increase the crop yield. Organic farming could be an option to ensure food, air, water, and soil quality, leaving the environment safe for the present and future generation. The crop plant performs always better when the demands of nutrients are being supplied by soil. The synchronization of nutrient release and uptake from plant are very much required (Anderson and Ingram, 1993; Myers et al., 1994). Experimental findings revealed that nonetheless of slow in break down and supply rate of nutrients from the organic source, they still maintaining the good organic matter content which helps the plant to uptake nutrient for longer time (Sharma and Mittra, 1991; Vanlauwe et al., 2004; Abou el-Magd et al., 2005). Eastern Himalayan region consumes least fertilizer in India; Arunachal Pradesh is the state where the use of fertilizer is only 2.5 kg ha^{-1} (Yadav, 2003). Farmers occasionally apply some organic wastes like swine and farm yard manure (Quedraogo et al., 2005; Vanlauwe and Giller, 2006). This has necessitated the research on use of organic manures on growth and yield on maize and its economics.

Materials and Methods

Experimental site

The field experiment was carried out in clay-loam soil at the experimental farm of ICAR Research Complex for NEH Region, Arunachal Pradesh Centre, Basar, located at West Siang District of Arunachal Pradesh, India during 2009 and 2010. The area falls under the humid sub tropical climate. The daily temperature during the study period varied widely between minimum of 13.2 ^{o}C to maximum 35.2 ^{o}C, received the average annual rainfall of 2365 mm. Physical and chemical parameters of the experimental site are given in table 2. The soil is acidic in reaction (pH 5.3), high in soil organic carbon (Walkaley and Black, 1.50%), available N (alkaline permanganate N, 205.6 kg ha^{-1}), available phosphorus (Olsen P, 8.3 kg ha^{-1}) and available K (Neutral normal ammonium acetate K, 260 kg ha^{-1}). Moisture retention at 0.03 and 1.5 MPa, bulk density and saturated hydraulic conductivity were 29.6% and 17.2%, 1.45 Mg m^{-3} and 532.1 mm hr^{-1}, respectively, in 0-20 cm soil depth.

Table 1. Field operation (days & month) for maize cultivation during experiment.

Activity	2009	2010
Treatment application	5th April	10th April
Sowing	25th April	30th April
Plant counts	10th May	15th May
Weeding	20th May & 9th June	25th May & 14th June
Earthing up	20th May	25th May
Pesticide application	5th and 28th June	10th June and 3rd July
Harvesting	10th September	15th September
Dehusking	25th September	30th September

Table 2. Initial soil characteristics of the experimental field (0-20 cm depth).

Sl. No.	Parameters	Mean value
1	pH	5.30
2	Organic carbon (%)	1.50
3	Available N (kg ha^{-1})	205.6
4	Available P (kg ha^{-1})	8.3
5	Available K (kg ha^{-1})	260.0
6	Bulk density (Mg m^{-3})	1.45
7	Particle density (Mg m^{-3})	2.70
8	Total porosity (%)	44.2
9	Maximum water holding capacity (%)	38.3
10	Field capacity (%)	20.0
11	Permanent wilting point (%)	9.4
12	Soil texture	Clay loam

Treatment application and specification

Maize (*Zea mays* L. *cv. All rounder*) was taken as test crop during the study. All the organic materials were applied in the soil 20 days before the sowing and mixed thoroughly into the soil. The nutrient contents of organic materials used during the experiment are given in the table 3. The experiment with six treatments *viz.* T_1: Vermicompost (VC; 2.5 Mg ha^{-1}), T_2: Poultry manure (PM; 1.25 Mg ha^{-1}), T_3: Swine manure (SM; 3.0 Mg ha^{-1}), T_4: Cow dung manure (CDM; 10.0 Mg ha^{-1}), T_5: Farm yard manure (FYM; 10.0 Mg ha^{-1}) and T_6: control was laid out on randomized completely block design with three replications. The organic sources of nutrients were supplied on the basis of recommended dose of nitrogen for the region (50 kg ha^{-1}). Planting geometry was maintained as per recommended spacing (60×30 cm). All other cultural practices have been done as per the scientific cultivation practices recommended to the region.

Table 3. Major nutrients in various organic sources (mean value of two years).

Organic manure	N (%)	P (%)	K (%)	C:N	Quantity applied (Mg ha^{-1})	N (kg)	P (kg)	K (kg)
Vermicompost (VC)	2.00	1.00	1.50	10	2.50	50.0	25.0	37.5
Poultry manure (PM)	4.00	1.60	1.80	16	1.25	50.0	20.0	22.5
Swine manure (SM)	1.67	1.17	1.49	18	3.00	50.0	35.1	44.7
Cow dung compost (CDM)	0.50	0.30	0.60	24	10.00	50.0	30.0	60.0
Farm yard manure (FYM)	0.50	0.25	0.40	26	10.00	50.0	25.0	40.0

Plant sampling and observations

Five plants of each plot were tagged and all the vegetative parameters (plant height and number of leaves), destructive parameters (leaf area and leaf area index (at 120 DAS), total dry matter of leaf, stem and cobs (at harvest)) were taken from observation rows. The yield parameters *viz.* number of cobs, number of rows, number of grains, cob diameters, cob length, test weight and shelling percent were recorded from the tagged plants. Grain and stover yield were recorded from net plot.

Chlorophyll content and solar radiation interception

Chlorophyll (SPAD value) was measured at 50 and 100 DAT by chlorophyll meter (SPAD-502 Plus) from three maize plants from net plot of each plot. Solar radiation interception was recorded with the help of Digital Lux Meter (TES 1332-TES Electrical Electronic Corporation) at noon 1.00 pm during clear sunny days.

Recovery, physiological and agronomic efficiencies

Recovery, physiological and agronomic efficiencies are measured by the nutrient supplied, nutrient uptake and grain yield harvested.

$$RE(\%)=[(T_{Nut} - T_{Nuc})/ (AN_t)]\times 100 \quad (1)$$

Where RE is the recovery efficiency, T_{Nut} and T_{Nuc} are the total N uptake in kg ha^{-1} by treatment and control, respectively, and AN_t is applied N in treatment in kg ha^{-1}.

$$PE=(GY_t - GY_c) / (T_{Nut} - T_{Nuc}) \quad (2)$$

$$AE=(GY_t - GY_c) / (AN_t) \quad (3)$$

Where *PE* and *AE* are the physiological and agronomic efficiency in kg grain kg^{-1} N uptake, GY_t and GY_c are the grain yield of treatment and control in kg ha^{-1}, respectively, T_{Nut} and T_{Nuc} are the total N uptake in kg ha^{-1} by treatment and control, respectively.

Soil Physical parameters

Bulk density (BD) and porosity were measured according to Majumdar and Singh (2000). Maximum water holding capacity was measured just after the rainfall.

Soil temperature

Soil thermometer was used to measure soil temperature (^{o}C) at 10 cm soil depth at 50 DAS with the help of soil thermometer.

Moisture releasing pattern

On the basis of gravitational method of water availability 0-20 cm soil depth of each plot were used to measure the maximum water holding capacity (MWHC), field capacity (FC) and permanent wilting point (PWP).

Field capacity was measured 48 hours after the rainfall, when the free flowing or gravitational water was removed and only water hold by the surface of soil. Permanent wilting point was measured after putting the pressure of 1.5 MPa on soil. It was assumed that all the pores filled with water is considered as maximum water holding capacity, the moisture status recorded at 0.03 MPa is called as field capacity and the amount of moisture was measured at 1.5 MPa is considered as permanent wilting point.

Economic analysis

Economic parameters (*viz.* cost of cultivation, gross returns, net returns and B: C ratio) were studied to identify the best organic sources in terms of money value.

Statistical analysis

Statistical analysis was carried out to know the variance for different parameters, effect of treatments, using standard statistical package (AGRES) and significance was identified in both 1 and 5% level while non-significant results were denoted as NS.

Results

Nutrient contents

The nutrient content of organic sources is given on table 3. PM has the highest nitrogen (N), phosphorus (P) and potassium (K) on dry weight basis followed by VC. However least N, P and K were measured on application of FYM. The vermicompost recorded the least C: N ratio, which are prerequisite for the organic nutrient sources. The highest C: N ratio was recorded on FYM.

Growth parameters

The growth parameters (plant height, numbers of leaves, leaf area, leaf area index and dry matter accumulation at various plant parts) were recorded higher on VC followed by PM (Table 4). However, the lowest vegetative parameters and dry matter accumulation at different plant parts were recorded on control. Similarly, CDM and FYM also recorded the lower value for the same parameters but were higher than the control.

Table 4. Influence on growth parameters of maize by various organic source of nutrient (mean value of two years).

Treatment	Plant height (cm)	Number of leaves	Leaf area (cm^2)	Leaf area index	Dry weight (g $plant^{-1}$)			TDM (g $plant^{-1}$)
					Leaf	Stem	Cobs	
VC (2.5 Mg ha^{-1})	201.7	12.0	1050.0	3.5	69.3	143.1	41.0	253.4
PM (1.25 Mg ha^{-1})	194.7	11.8	963.3	3.2	64.0	132.1	36.0	232.1
SM (3.0 Mg ha^{-1})	193.0	11.6	900.0	3.0	60.0	119.0	32.0	211.3
CDM (10.0 Mg ha^{-1})	188.3	11.5	783.3	2.6	57.0	110.5	29.0	196.5
FYM (10.0 Mg ha^{-1})	187.3	11.4	720.0	2.4	54.0	114.9	30.0	198.9
Control	174.3	11.1	630.0	2.1	46.0	105.1	22.0	173.1
CD (P=0.05)	7.96**	NS	57.87**	0.41**	6.28**	7.95**	5.56**	29.72**

NS: non significant, * Significant at 5% and ** Significant at 1%.

Physiological parameters

The highest SPAD value of chlorophyll content at 50 and 100 DAS was observed on VC and the least value was observed on control (Table 5). Similarly, solar radiation interception at middle and bottom was recorded higher when crop was applied with VC followed by PM.

Table 5. Influence of physiological parameters of maize by various organic source of nutrient (mean value of two years).

Treatment	Chlorophyll content (SPAD)		Solar radiation interception (%)	
	50 DAS	100 DAS	Middle	Bottom
VC (2.5 Mg ha^{-1})	35.1	36.2	52.6	78.1
PM (1.25 Mg ha^{-1})	33.3	34.6	49.3	75.2
SM (3.0 Mg ha^{-1})	32.5	33.8	47.1	73.6
CDM (10.0 Mg ha^{-1})	31.7	33.0	45.8	71.7
FYM (10.0 Mg ha^{-1})	30.4	32.7	43.2	70.2
Control	28.3	32.0	41.5	68.4
CD (P=0.05)	4.21*	NS	6.80*	8.31*

Yield attributes and yield

The crop which received no organic manure (control) came to early flowering due to lack of nutritional supply. VC applied plants were 7.3 days late flowering, where crop plants completed their basic vegetative phase little later and accumulated the substitute for flowering. 50% flowering of rest of the treatments recorded in between the control and VC. Yield attributing characters like no. of cobs plant^{-1}, no. of grain rows cob^{-1}, no. of grains row^{-1}, cob diameter, cob length, test weight and shelling per cent were recorded higher on VC applied plots followed by PM (Table 6). Test weight did not show any specific trend and highest test weight was recorded when crop was supplied with CDM followed by FYM. However, the least test weight was recorded on control. The highest grain yield of maize was recorded on VC followed by PM (Table 6); it might be due to the fact that all the yield attributes were recorded higher for the same treatment. However the lowest grain yield was recorded on control. Similarly, stover yield was recorded higher with VC followed by poultry manure.

Nutrient uptake

It was noticed that VC applied treatments removed 202, 167, 211% of N, P and K respectively over control followed by PM (171, 158, 167% (Table 7). The swine manure application in maize uptakes 135, 117, 144%, respectively for N, P and K but the maize grown under CDM and FYM uptakes 114, 83, 92 and 107, 50 and 48% higher N, P, K respectively over the control.

Agronomic and physiological efficiency

VC recorded the highest recovery efficiency followed by PM over control (Table 8) whereas; the physiological recovery was recorded higher for SM followed by PM. The agronomic efficiency was recorded higher for VC followed by PM. Maize crop responded well to VC and PM, to produce more yield attributes and yield.

Table 6. Yield attributes and yields of maize as influence by various organic sources of nutrients (mean value of two years).

Treatment	50% Flowering (days)	Number of cobs	Number of rows	Number of grains	Cob diameter (cm)	Cob length (cm)	Test weight (g)	Shelling percentage (%)	Yield (kg ha^{-1})	Straw yield (kg ha^{-1})
VC (2.5 Mg ha^{-1})	54.1	1.6	17.9	32.4	8.5	18.4	283.3	83.7	4350.0	6330.0
PM (1.25 Mg ha^{-1})	53.3	1.4	17.2	29.0	7.8	17.5	285.0	81.1	4130.0	6210.0
SM (3.0 Mg ha^{-1})	52.6	1.2	15.3	27.5	7.3	16.4	290.2	79.8	3787.0	5876.0
CDM (10.0 Mg ha^{-1})	50.4	1.1	14.9	26.5	7.1	15.5	306.3	78.1	3356.0	5686.0
FYM (10.0 Mg ha^{-1})	48.6	1.1	14.5	25.4	6.9	15.0	301.7	77.2	3200.0	5432.0
Control	47.0	1.0	14.0	23.1	6.2	13.4	270.0	74.7	1900.0	4862.0
CD (P=0.05)	NS	0.12^{**}	1.01^{**}	5.0^{*}	0.65^{**}	1.24^{**}	20.70^{*}	3.63^{**}	415.03^{**}	523.04^{**}

Table 7. Uptake of N, P and K (kg ha^{-1}) on grain + straw of maize by different organic source of nutrient at harvest (mean value of two years).

Treatment	N	P	K
VC (2.5 Mg ha^{-1})	85.0	32.0	84.0
PM (1.25 Mg ha^{-1})	76.0	31.0	72.0
SM (3.0 Mg ha^{-1})	66.0	26.0	66.0
CDM (10.0 Mg ha^{-1})	60.0	22.0	52.0
FYM (10.0 Mg ha^{-1})	58.0	18.0	40.0
Control	28.0	12.0	27.0

Table 8. Influence of organic sources of nutrients on various efficiency parameters (mean value of two years).

Treatment	Recovery efficiency (%)	Physiological efficiency (kg grain kg^{-1} N uptake)	Agronomic efficiency (kg grain kg^{-1} N applied)
VC (2.5 Mg ha^{-1})	114	42.98	49.0
PM (1.25 Mg ha^{-1})	96	46.46	44.6
SM (3.0 Mg ha^{-1})	76	49.66	37.7
CDM (10.0 Mg ha^{-1})	64	45.50	29.1
FYM (10.0 Mg ha^{-1})	60	43.30	26.0
Control	-	-	-

Physical parameters of soil

The physical parameters of soil like porosity and maximum water holding capacity were recorded more on FYM followed by CDM (Figure 1 a, b, c, d and e). Similarly, water content at field capacity and permanent wilting point was recorded higher on VC. However, the least value was recorded on control. The bulk density was recorded lower when FYM and CDM were applied in to the soil. VC resulted very high ‘porosity’, ‘aeration’, ‘drainage’ and ‘water holding capacity’ which lead to vast surface area, providing strong absorbability and retention of nutrients.

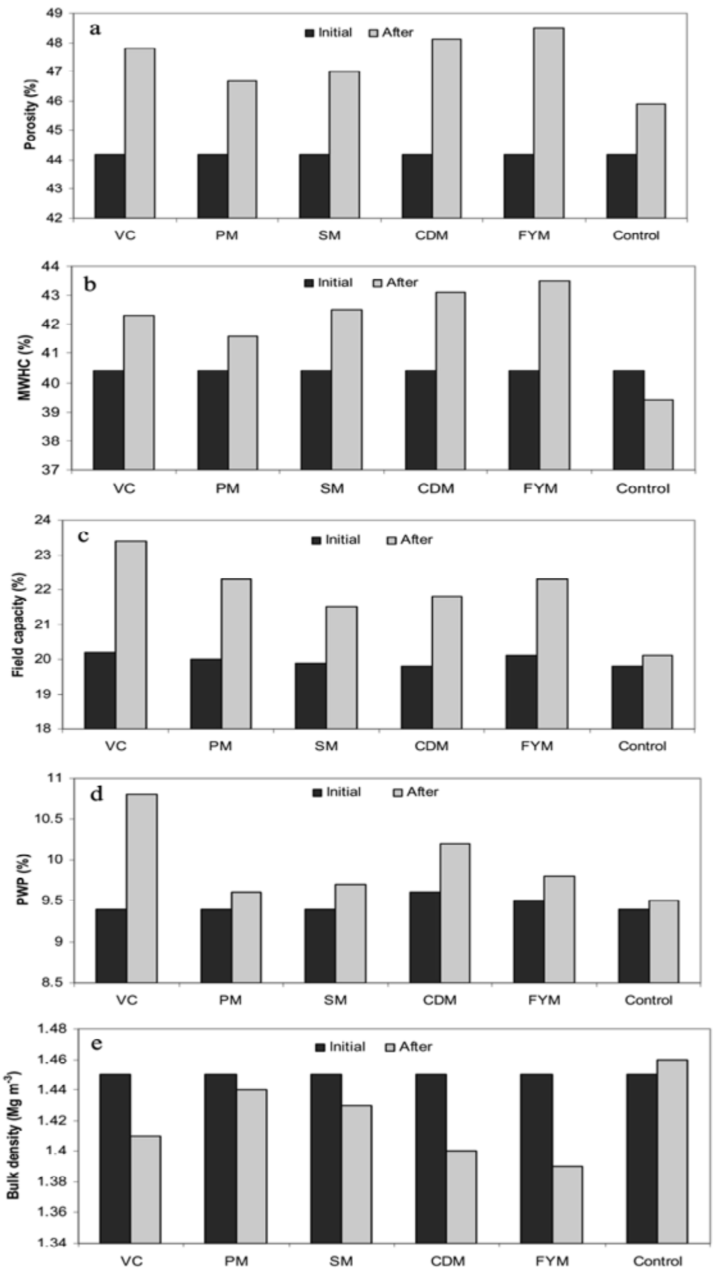

Figure 1. Physical parameters of soil as influenced by various organic source of nutrients on maize 1a: porosity; 1b: maximum water holding capacity; 1c: Field capacity; 1d: permanent wilting point and 1e: bulk density.

Soil temperature

The highest soil temperature was recorded when soil was not applied with any organic source of nutrient (Figure 2), whereas the lowest soil temperature was measured on VC followed by PM.

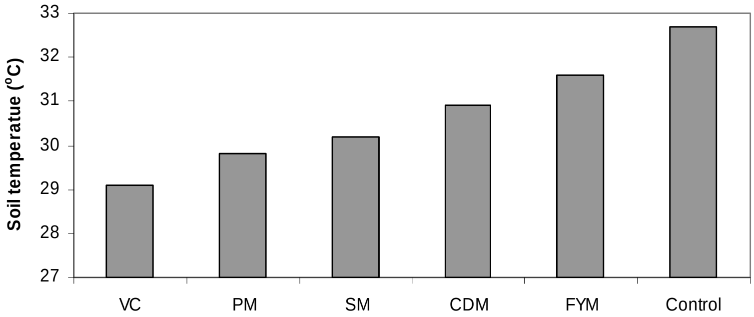

Figure 2. Soil temperature at 20 cm depth as influenced by various organic sources of nutrients on maize.

Moisture releasing pattern

It was recorded that the availability of moisture for maize was higher during early stage on CDM and FYM (Figure 3), but as time progressed the release of moisture from the soil was higher and finally at the end of the moisture available cycle or dry spell the availability of moisture was least on the above treatment. However, VC have the consistent water availability for crop plants and the moisture content on soil at the end of irrigation cycle or dry spell.

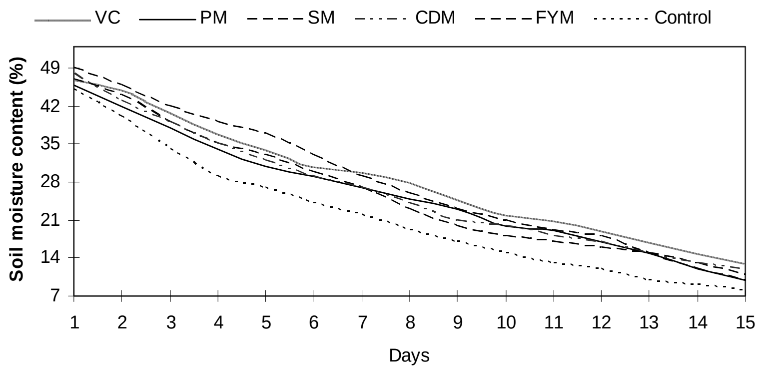

Figure 3. Moisture releasing pattern as influenced by various organic source of nutrients on maize.

Chemical parameters of soil

Chemical parameters of soil were largely influenced by organic source of applied nutrient (Figure 4 a, b, c, d and e). The pH was recorded higher on VC treated plot followed by SM. However lower pH was recorded on control. Organic carbon was recorded higher on CDM followed by FYM. This may be due to the application of higher rate of organic manure. However, the lowest organic carbon was measured on control. Similarly, VC treated plot recorded higher content of available N, P and K followed by PM. However the availability of N, P and K was recorded lower on control than the initial status of soil.

Economics

The economic analysis was done for the experiment, showed that the cost of cultivation was higher for the VC followed by SM (Table 9). Whereas, the gross return was recorded higher for VC followed by PM. However, the net return was recorded higher for PM followed by VC. The Benefit cost ratio was recorded 52.3, 26.2 and 19.2% higher for PM, CDM and SM respectively over control. Though the B: C ratio was comparatively lower for VC, due to its yield and other sustainability advantages it was superior to other treatments.

Table 9. Economics of the maize under various organic sources of nutrients (only for 2010).

Particular	VC (2.5 Mg ha^{-1})	PM (1.25 Mg ha^{-1})	SM (3.0 Mg ha^{-1})	CDM (10.0 Mg ha^{-1})	FYM (10.0 Mg ha^{-1})	Control
Cost of cultivation (Rs ha^{-1})	8500	8500	8500	8500	8500	8500
Cost of treatment (Rs ha^{-1})	10000	5000	6000	4000	5000	-
Total cost of cultivation (Rs ha^{-1})	18500	13500	14500	12500	13500	8500
Gross return (Rs ha^{-1})	42315	40275	37021	33047	31516	19531
Net return (Rs ha^{-1})	23815	26775	22521	20547	18016	11031
B:C ratio	1.29	1.98	1.55	1.64	1.34	1.30

Price of maize grain Rs 9000 Mg^{-1}, Stover Rs 500 Mg^{-1}, VC @ 4000 Mg^{-1}, PM @ 4000 Mg^{-1}, SM @ 2000 Mg^{-1}, CDM @ 400 Mg^{-1}, FYM @ 500 Mg^{-1}, [Rs 50= 1 USD].

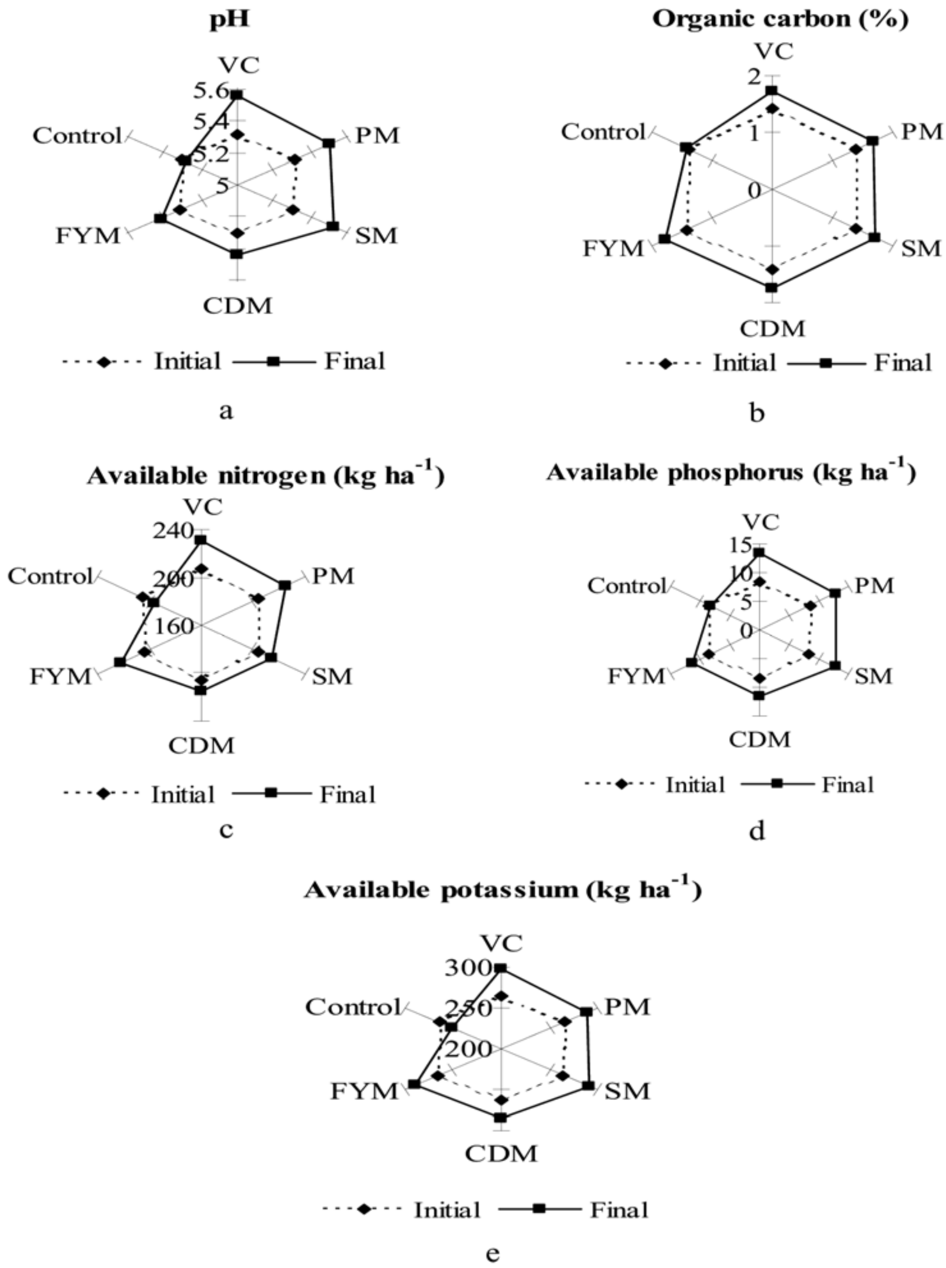

Figure 4. Chemical parameters of soil as influenced by various organic sources of nutrients on maize 4a: pH; 4b: organic carbon; 4c: available N; 4d: available P and 4e: available potassium.

Discussion

Growth parameters

Higher growth rate (Table 4) on VC plot was due to the more availability of plant nutrients, enzymes, vitamins and congenial soil characters which helped the plant to uptake more soil nutrient along with water (Satyanarayana et al., 2002; Adeniyan and Ojeniyi, 2005; Channappagoudar et al., 2007; Ayoola and Makinde, 2008). Organic manure especially VC supply balanced nutrients to plant roots and stimulate growth, increase organic matter content of the soil including the 'humic substances' that affect nutrient accumulation and promote root growth (Siminis et el., 1998; Canellas et al., 2000).

Physiological Parameters

VC supply micronutrients like Mg^{2+}, which helped in synthesis of chlorophyll constituents (Nehra et al., 2001; Sanwal et al., 2007). Higher solar radiation interception by applying VC might be due to the better growth parameters like leaf area and leaf area index, which helped the solar radiation to fall on the leaves and least radiation, was intercepted to the soil (Table 5). However, control plots have least leaf area and leaf area index, therefore, interception on soil was more (Anburani and Manivannan, 2002; Choudhary et al., 2006).

Yield attributes and yield

Higher chlorophyll content and solar radiation intercepted on various growth stage of plant on VC treatment resulted into higher yield and yield attributes (Table 6). Better harvesting of solar radiation and more chlorophyll contents helped the plant to accumulate more photosynthates to the leaves, stem and reproductive parts (Choudhary et al., 2006). Similar findings were recorded by Satyanarayana et al. (2002) and Adeniyan and Ojeniyi (2005). All the yield attributes was recorded higher in VC as it contains enzymes like amylase, lipase, cellulase and chitinase, which continue to break down organic matter in the soil to release the nutrients and make it available near rhizosphere and finally absorbed by the plant roots (Tiwari et al., 1989; Lunt and Jacobson, 1994; Chaoui et al., 2003).

Nutrient uptake

Applied composts worked as a ‘slow-release fertilizer’ Therefore, organically supplied plants have more opportunity to uptake nutrients continuously for longer time (Table 7). Organic sources of nutrient in fact improve the total physical and chemical properties of the soil (Figures 1 and 4). They also add useful micro-organisms to the soil and provide food for the existing soil micro-organisms and thus increase their biological properties and capacity of self-renewal of soil fertility (Shiralipour et al., 1992; Quedraogo et al., 2001; Sujatha et al., 2008).

Agronomic and physiological efficiency

The highest recovery efficiency on VC followed by PM was due to the fact that more applied nitrogen was absorbed by maize plants with better physical and chemical condition of soil which supplied the more available N. Whereas, the physiological recovery was recorded higher for SM followed by PM (Table 8). This is because of comparative yield produced with unit kg N uptake over control and the grain yield produced over control was higher for uptake of per kg N. The agronomic efficiency was recorded higher for VC due to additional grain yield of maize produced with per kg of N applied.

Physical parameters of soil

Higher volume of FYM and CDM applications, not only pulverize the soil but also hold more water on surface and space between the pores (Carter, 2002; Wilhelm et al., 2004) thus resulted maximum water holding capacity (Figure 1b). Beneficial effects of reduced bulk density by addition of organic sources have been reported by Kumpawat (2004). Present study showed that soil amended with VC along with other organic manures recorded significantly lower ‘soil bulk density’ and hence porous, lighter and least compacted soil (Figure 1e). Increase in porosity has been attributed to increased number of pores in the 30-50 µm and 50-500 µm size ranges and decrease in number of pores greater than 500 µm (Nighawan and Kanwar, 1952; Lunt and Jacobson, 1994).

The variation in soil temperature may be due to applied VC and PM helped the soil for better holding of moisture (Figures 2 and 3). But control had no such advantages, air circulation was not proper and due to dryness soil was comparatively hotter (Agehera and Warncke, 2005; Sanwal et al., 2007). FYM and CDM hold more moisture on soil surface but as time progresses the moisture release was more (Agehera and Warncke, 2005; Sarwad et al., 2005). However, control has recorded the lower available water throughout the irrigation cycle/ dry spell because of no addition of organic inputs.

Chemical parameters

The increase in pH on VC applied plots was due to the suppression of the activity of Fe and Al oxides and hydroxides, which played a vital role in protonization-deprotonization mechanism, controlling H^+ ion concentration in soil solution (Figure 4). The higher value of pH on VC treated plot was due to the fact that the excretion of NH_4^+ ions from calciferous glands of earthworms, the worm casts had a pH near to neutral range (Baskar et al., 1994). Higher application of organic manure on CDM and FYM helped the soil to build more organic carbon (Follott, 2001; Madukwe et al., 2008). Higher availability of maximum nutrients on VC plot was due to availability of more surface area and enhanced the soil enzyme activities like dehydrogenase and phoshpatase. This improves the microbial activity and decomposes the organic matter more rapidly. VC with higher amount of active humic fraction having high CEC had thus resulted in maximum enhancement of this parameter (Bremner and Mulvaney, 1978). The process of aminization, amonification, and oxidative deaminisation brought about by microbially mediated enzyme systems are active in VC and other organic amendments, thus contributing more of soluble N (Bhaskaran and Devi, 2009). The high microbial activity and enhanced mineralization of soil P coupled with high phosphatase activity are the reasons for high available P. K^+ ions from edge, wedge, or inter layer sites within clay minerals, could possibly be replaced by NH_4^+ ions of similar ionic radius, so the concentration of which was increased in the presence of VC (Bornke and Lavkulish, 1999; Sanyal, 2002; Madukwe et al., 2008; Bhaskaran and Devi, 2009). Organic matters improved soil structure, water infiltration, and soil water holding capacity besides increased the ability of the soil to hold plant nutrients by improving the soil cation exchange capacity. Organic matter provided by VC is quickly decomposed by soil microorganisms and does not persist for long in the soil but their effect will be for longer time (Valenzuela and Smith, 2002).

Economics

The cost of cultivation was recorded higher on VC followed by SM and least was recorded on control (Table 9). This might be due to the higher cost involved in these organic sources. The gross and net returns were recorded higher on VC followed by PM and least on control. The B: C ratio was recorded higher with PM followed by CDM. The least B: C ratio on VC followed by control. This was due to the cost involved in production of maize and return harvested from the investments (Sujatha et al., 2008; Premsekhar and Rajshree, 2009).

Conclusions

Production of maize under the various organic sources of nutrients increased the growth, yield attributes and yield. Similarly, applied organic sources of nutrient improved the physical and chemical properties of soil. VC and PM applied plots recorded the higher available nutrient to crop plants and supply for the longer time. Arunachal Pradesh where farmers hardly use any chemical fertilizer, these easily available organic nutrient sources can be used for higher production. In addition, it reduces the soil and water pollution and gives quality, healthy and nutritious crop produces.

Acknowledgements

The authors sincerely acknowledge to the Director, ICAR-RC-NEH Region for providing all the financial assistance. We also extend our gratitude to the Joint Director, of ICAR-RC-NEH Region Arunachal Pradesh Centre for facilitating the laboratory facilities, also thanks to the technical staff of the centre for their kind cooperation for conducting the study successfully.

References

Abou El-Magd, M.M., Hoda, M.A., Fawzy, Z.F., 2005. Relationships, growth, yield of broccoli with increasing N, P or K ratio in a mixture of NPK fertilizers. Annals Agric. Sci. Moshtohor. 43 (2), 791-805.

Adeniyan, O.N., Ojeniyi, S.O., 2005. Effect of poultry manure, NPK 15-15-15 and combination of their reduced levels on maize growth and soil chemical properties. Niger. J. Soil Sci. 15, 34-41.

Agehara, S., Warncke, D.D., 2005. Soil moisture and temperature effects on nitrogen release from organic nitrogen sources. Soil Sci. Soc. Am. J. 69, 1844-1855.

Anburani, A., Manivannan, K., 2002. Effect of integrated nutrient management on growth in brinjal. South Indian Hort. 50 (4-6), 377-386.

Anderson, J.M., Ingram, J.S.I., 1993. Tropical soil biology and fertility. In: (Ed.), A Handbook of Methods, 2nd ed. CAB International, Wallingford, U.K.

Ayoola, O.T., Makinde, E.A., 2008. Performance of green maize and soil nutrient changes with fortified cow dung. African J. Plant Sci. 2 (3), 19-22.

Basker A., Kirkmon, J.H., Macqrger, A.N., 1994. Changes in potassium availability and other soil properties due to soil ingestion by earthworms. Biol. Fertil. Soils, 17, 154-158.

Bhaskaran, U.P., Devi, K., 2009. Effect of organic farming on soil fertility, yield and quality of crops in the tropics. UC Davis: The Proceedings of the International Plant Nutrition Colloquium XVI.

Bornke, A.A., Lavkulish, L.M., 1999. Composition of poultry manure and effect of heavy application on soil chemical properties. Plant Nutr. 1, 611-637.

Bremner, J.M., Mulvaney, R.L., 1978. Urease activity in soils. Soil Enzymes. Academic Press, London, pp. 149-196.

Canellas, L.P., Olivares, F.L., Okorokova, A.L., Facanha, R.A., 2000. Humic acids isolated from earthworm compost enhance root elongation, lateral root emergence and plasma membrane H^+-ATPase activity in maize roots. Inter. J. Plant Physiology, 130, 1951-1957.

Carter, M.R., 2002. Soil quality for sustainable land management: Organic matter and aggregation interactions that maintain soil functions. Agron. J. 94, 38-47.

Channappagoudar, B.B., Biradar, N.R., Patil, J.B., Gasimani, C.A.A., 2007. Utilization of weed biomass as an organic source in sorghum. Karnataka J. Agric. Sci. 20 (2), 245-248.

Chaoui, H.I., Zibilske, L.M., Ohno, T., 2003. Effects of earthworms casts and compost on soil microbial activity and plant nutrient availability. Soil Biology and Biochemistry, 35 (2), 295-302.

Choudhary, V.K., Ramachandrappa, B.K., Nanjappa, H.V., Bachkaiya, V., 2006. Yield, economics, quality, sensory evaluation and solar radiation interception as influenced by planting methods and drip irrigation levels in Baby corn (*Zea mays* L.) vegetable. J. Asian Hort. 2 (1), 45-48.

DoA., 2008-09. Department of Agriculture, Government of Arunachal Pradesh, pp. 1-120.

Follott, R.F., 2001. Soil management concepts and carbon sequestration in cropland soils. Soil Till. Res. 61, 77-92.

Kumpawat, B.S., 2004. Integrated nutrient management for maize (*Zea mays*)–Indian mustard (*Brassica juncea*) cropping system. Indian J. Agron. 49, 18-21.

Lunt, H.A., Jacobson, H.G., 1994. The chemical composition of earthworm casts. Soil Science, 58, 367-75.

Madukwe, D.K., Christo, I.E.C., Onuh, M.O., 2008. Effects of organic manure and cowpea (*Vigna unguiculata* (l.) walp) varieties on the chemical properties of the soil and root nodulation. Science World J. 3 (1), 43-46.

Majumdar, S.P., Singh, R.A., 2000. (ed) Analysis of Soil Physical Properties. Agrobios, New Delhi, India.

Myers, R.J.K., Palm, C.A., Cuevas, E., Gunatilleke, I.U.N., Brossard, M., 1994. The synchronization of nutrient mineralization and plant nutrient demand. In: Woomer, P.I., Swift, M.J. (ed.) The Biological Management of Tropical Soil Fertility, John Wiley and Sons, Chichester, UK. pp. 81-116.

Nehra, A.S., Hooda, I.S., Singh, K.P., 2001. Effect of integrated nutrient management on growth and yield of wheat (*Triticurn aestivum L.*). Indian J. Agron. 45, 112-117.

Nighawan, S.D., Kanwar, J.S., 1952. Physico-chemical properties of earthworm castings. Indian J. Agric. Sci. 22, 357-375.
Premsekhar, M., Rajashree, V., 2009. Influence of organic manures on growth, yield and quality of okra. American-Eurasian J. Sustain. Agric. 3 (1), 6-8.
Quedraogo, E., Mando, A., Stroosnijder, L., 2005. Effects of tillage, organic resources and nitrogen fertilizer on soil carbon dynamics and crop nitrogen uptake in semi-arid West Africa. Soil Till. Res. 91, 57-67.
Quedraogo, E., Mando, A., Zombre, N.P., 2001. Use of compost to improve soil properties and crop productivity under low input agricultural system in West Africa. J. Agric. Ecosys. Environ. 84, 259-266.
Sanwal, S.K., Lakminarayana, K., Yadav, R.K., Rai, N., Yadav, D.S., Mousumi, B., 2007. Effect of organic manures on soil fertility, growth, physiology, yield and quality of turmeric. Indian J. Hort. 64 (4), 444-449.
Sanyal, S.K., 2002. Soil Colloids. In: Fundamentals of Soil Science (ed) Sekhon, G.S., Chhonkar, P.K., Das, D.K., Goswami, N.N., Narayanasamy, G., Poonia, S.R., Rattan, R.K., Sehgal, J.). Indian Soc. Soil Sci., New Delhi, pp. 229-260.
Sarwad, I.M., Guled, M.B., Gundlur, S.S., 2005. Influence of integrated nutrient supply system for rabi sorghum-chickpea crop rotation on crop yields and soil properties. Karnataka J. Agric. Sci. 18, 673-679.
Satyanarayana, V., Vara Prasad, P.V., Murthy, V.R.K., Boote, K.J., 2002. Influence of integrated use of farmyard manure and inorganic fertilizers on yield and yield components of irrigated lowland rice. J. Plant Nutr. 25, 2081-2090.
Sharma, A.R., Mittra, B.N., 1991. Effect of different rates of application of organic and nitrogen fertilizers in a rice-based cropping system. J. Agric. Sci. (Cambridge) 117, 313-318.
Shiralipour, A., Mc Connell, D.B., Smith, W.H., 1992. Uses and benefits of MSW compost: A review and assessment. J. Biomass and Bioenergy. 3, 267-279.
Siminis, C.I., Loulakis, M., Kefakis, M., Manios, T., Manios, V., 1998. Humic substances from compost affect nutrient accumulation and fruit yield in tomato. Acta Hort. 469, 353-358.
Sujatha, M.G., Lingaraju, B.S., Palled, Y.B., Ashalatha, K.V., 2008. Importance of integrated management practices in maize under rainfed condition. Karnataka J. Agric. Sci. 21 (3), 334-338.
Tiwari, S.C., Tiwari, B.K., Mishra, R.R., 1989. Microbial populations, enzyme activities and nitrogen-phosphorus-potassium enrichment in earthworm casts and in surrounding soil of a pineapple plantation. J. Biol. and Fert. Soils. 8, 178-182.
Valenzuela, H., Smith, J., 2002. Green Manure Crops: Cowpea. Sustainable agriculture, Green Manure Crops, pp. 1-3.
Vanlauwe, B., Giller, K.E., 2006. Popular myths around soil fertility management in sub-Saharan Africa. Agric. Ecosyst. Environ. 116, 34-46.
Vanlauwe, B., Sanginga, N., Giller, K.E., Merckx, R., 2004. Management of nitrogen fertilizer in maize-based systems in sub humid areas of sub- Saharan Africa. In: Mosier A.R., Syers, J.K., Freney, J.R. (ed). Agriculture and the nitrogen cycle: SCOPE No. 65. Island Press, Washington, USA, pp. 115-127.
Wilhelm, W.W., Johnson, J.M.F., Hatfield, J.L., Voorhees, W.B., Linden, D.R., 2004. Crop and soil productivity response to corn residue removal: A literature review. Agron. J. 96 (1), 1-17.
Yadav, J.S.P., 2003. Managing soil health for sustained high productivity. J. Indian Soc. Soil Sci. 51 (4), 448-465.