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DETERMINATION OF OPTIMUM FARMYARD MANURE AND NP FERTILIZERS FOR MAIZE ON FARMERS' FIELDS

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ABSTRACT

A study was initiated in 1997 to introduce the culture of supplementing low rates of NP fertilizers with farmyard manure (FYM) in the maize based farming systems of western Oromia. The treatments were 0/0, 20/20, 40/25 and 60/30 kg N/P ha^{-1} and 0, 4, 8, and 12 t FYM ha^{-1} in factorial arrangement in a randomized complete block design with three replications. The experiment was conducted at Laga Kalla, Walda, Shoboka, Harato, and Bako Research Center using BH-660 hybrid maize. The FYM used for the experiment was well decomposed under shade and spot applied together with the P fertilizer at planting; N was applied in split form. The residual effects of FYM were investigated for Laga Kalla, Walda and Shoboka during the 1998 cropping season. Statistical analysis revealed that the N/P fertilizers and FYM significantly ($p<0.05$) increased grain yield in all locations except for Walda in 1997. Interactions of FYM and NP fertilizer rates were significant ($p\leq0.05$) at all locations except for Shoboka. The application of FYM alone at rates of 4, 8, and 12 t ha^{-1} produced average grain yields of 5.76, 5.61 and 5.93 t ha^{-1}, respectively, compared to 3.53 t ha^{-1} for the control treatment. Laboratory analysis confirmed that considerable amounts of macronutrients and small amounts of micronutrients were supplied by the FYM. There were significant residual effects of FYM and NP fertilizers applied in 1997 on maize grain yields in 1998. Based on the results of this study, the integrated use of properly managed FYM and low rates NP fertilizers could be used for maize production in the areas under consideration. Moreover, sole applications of FYM on relatively fertile soils like Walda and Harato are useful in maintaining soil fertilty and are encouraging for resource poor farmers.

Key Words: Farmyard manure, integrated nutrient management, NP fertilizers, residual effects, Ethiopia

INTRODUCTION

Low soil fertility is one among the major factors limiting maize production and productivity in western Oromia, Ethiopia. This is common in many tropical cropping systems where fertilizer use is low and little or no agricultural residues are returned to the soil for maintaining soil fertility. Alfisols that are moderately acidic in reaction are the dominant soil type in the region. These soils are characterized by low cation exchange capacity (CEC), and low contents of organic matter, available phosphorus (P) and total nitrogen (N) (Asfaw et al., 1997; Wakene, 2001). Moreover, the soils are fragile and easily affected by intensive cultivation and continuous use of inorganic fertilizers. As a result, considerable areas of land at the Bako Agricultural Research Center have been abandoned from production during the past three decades (Wakene, 2001). Several other natural and socioeconomic factors are also involved in aggravating the decline in soil productivity under the farming community in the region with the result that the relatively common practice of sole application of NP fertilizers has not sustained maize production and productivity in the region.

The recommended rates of inorganic fertilizers for hybrid maize production in western Oromia are 110 kg N and 20 kg P ha^{-1}. The recommendation was initially adopted by the well-to-do farmers but when the fertilizer subsidy was removed by the Government and the price of inorganic fertilizers doubled, the farmers failed to use even one-third of the recommended rates. Therefore, to maintain soil fertility and enhance their productivity, the use of other alternative options of soil fertility replenishment is indispensable. Farmyard manure (FYM) is one potential source of nutrients as a result of the high cattle population in the region where on average there are 6.1 cattle per family (Legesse et al., 1987).

There exists a large volume of literature reporting the the efficiency and effectiveness of FYM and other organic nutrient sources in maintaining soil fertility, improving crop yields and sustaining productivity, and that display their increased potential when integrated with inorganic fertilizers (Grant, 1981; Mugwira, 1985; Lyimo & Temu, 1992; Inckel et al., 1996; Asfaw et al., 1997; Asfaw et al., 1998; Heluf et al., 1999; Heluf, 2002; Wakene et al., 2002). Studies in Zimbabwe indicated that manure alone generally resulted in low crop yield indicating a need to supplement with inorganic fertilizers on soils low in fertility (Grant, 1981; Mugwira, 1985). At Uyole in Tanzania, application of low rates of NP fertilizers with FYM produced 7.10 t ha^{-1} of maize grain compared to 4.03 t ha^{-1} when the same rates of NP were used alone (Lyimo & Temu, 1992). Heluf (2002) reported an increment of 0.47 t ha^{-1} in grain yield of maize due to application of FYM during the first year over no FYM, whereas increasing FYM applications from 0-20 t ha^{-1} increased wheat grain yield from 1.97 to 3.31 t ha^{-1} on Vertisols of Hirna valley in western Hararghe zone, Ethiopia.

The potential of organic sources increases when used together with mineral fertilizers. While evaluating the potential of compost and its integration with low rates of NP fertilizers for improvement of maize production in western Oromia, Wakene et al. (2002) observed a higher marginal rate of return (MRR) when half the recommended N/P fertilizer rate was combined with 5 t compost ha^{-1} compared to MRR for the recommended NP rate alone (MRR of 151% vs. 61%, respectively). The use of crop residues with freshly applied and with residual NP fertilizers increased maize grain

Table 1. The soil pH, texture, total N (TN), organic carbon (OC) and available P of the experimental sites before and after treatments application

Location	Yr	N/P	+ FYM	pH (1:2.5)		OC	TN	Particle size (%)			Texture	Avail P (mg kg^{-1})	
				H_2O	KCl	(%)		Sa	Si	Cl		Olsen	Bray
Bako Research Center	97	0/0	+ 0	5.24	4.10	2.03	0.18	39	29	32	CL	2.68	2.80
	99	0/0	+ 12	5.17	3.99	2.15	0.18	40	31	29	CL	4.18	5.20
	99	60/30	+ 0	5.05	3.67	1.56	0.13	33	29	28	CL	9.48	10.12
	99	60/30	+ 12	5.65	4.30	1.88	0.14	38	25	27	SCL	7.62	8.33
Shoboka	97	0/0	+ 0	5.30	4.04	2.57	0.22	29	37	34	CL	3.06	2.80
	99	0/0	+ 12	5.05	4.00	1.76	0.14	30	36	34	CL	4.21	6.71
	99	60/30	+ 0	5.20	4.12	1.76	0.13	31	37	32	CL	3.86	4.20
	99	60/30	+ 12	5.42	4.20	2.35	0.23	29	38	23	L	3.10	4.21
Laga Qalla	97	0/0	+ 0	5.25	4.35	2.17	0.20	39	33	28	CL	3.86	4.50
	99	0/0	+ 12	5.73	4.24	2.87	0.26	40	32	28	CL	4.46	12.41
	99	60/30	+ 0	5.71	4.42	2.85	0.24	38	36	26	L	7.64	7.26
	99	60/30	+ 12	5.33	4.21	3.25	0.33	39	34	27	L	10.3	8.25
Walda	97	0/0	+ 0	5.64	4.12	2.21	0.24	39	31	30	CL	3.20	2.50

CL = Clay loam, SCL = Sandy clay loam, L = Loam, S = Sand, Si = Silt, C = Clay, Bray = Bray II method, Tex = Textural class, Yr = year, 97 = 1997 = soil samples collected before treatments application, 99 = 1999 = soil samples taken after treatments application

Table 2. The exchangeable bases, exchangeable acids, CEC, percent base saturation of the experimental sites before and after treatments application

Location	Yr	N/P	+ FYM	Exchangeable bases, acid and CEC (cmol$_c$ kg^{-1})							PBS (%)
		(kg	+ t ha^{-1})	Na	K	Ca	Mg	Acid	Al	CEC	
Bako Research Center	97	0/0	+ 0	0.44	0.47	4.59	1.92	0.56	Tr.	24.6	30
	99	0/0	+ 12	0.63	1.38	4.99	1.33	0.45	Tr.	25.2	33
	99	60/30	+ 0	0.39	0.72	2.94	0.83	0.36	Tr.	15.0	40
	99	60/30	+ 12	0.79	1.99	3.79	1.25	0.52	Tr.	19.4	62
Shoboka	97	0/0	+ 0	0.38	1.23	15.0	6.50	0.12	Tr.	37.2	62
	99	0/0	+ 12	0.39	0.59	4.14	1.08	0.32	Tr.	20.2	31
	99	60/30	+ 0	0.47	0.87	3.99	1.00	0.51	Tr.	21.0	30
	99	60/30	+ 12	0.55	1.28	7.88	2.50	0.40	Tr.	33.8	36
Laga Qalla	97	0/0	+ 0	0.31	1.91	4.69	2.08	0.16	Tr.	23.2	30
	99	0/0	+ 12	0.87	2.32	7.83	1.83	0.23	Tr.	31.4	39
	99	60/30	+ 0	0.63	1.79	8.78	2.08	0.12	Tr.	30.6	31
	99	60/30	+ 12	0.79	2.09	6.24	1.75	0.21	Tr.	35.0	41
Walda	97	0/0	+ 0	0.40	1.64	8.48	2.25	0.24	Tr.	24.0	53

PBS = percent base saturation, Yr = year, 97 = 1997 = soil samples collected before treatments application,
99 = 1999 = soil samples taken after treatments application, Tr = trace

yields by 1.31 and 0.54 t ha^{-1}, respectively, on Vertisols (Typic Pellusterts), and by 0.85 and 0.57 t ha^{-1}, respectively, on Inceptisols (Typic Ustorthents) in the Alemaya area of Ethiopia (Heluf et al., 1999). Asfaw et al. (1998) also reported significant increases in maize grain yields on Inceptisols and Vertisols in the Alemaya area due to crop residue application. Crop residues applied with recommended NP fertilizers produced 52% more sorghum grain on Inceptisols in the Alemaya area than crop residues applied alone (Asfaw et al., 1997).

Despite the high number of cattle per household (average of 6.1) and the availability of cheap family labor that could be used for FYM collection, incubation and transportation (Legesse et al., 1987), the use of FYM for soil fertility maintenance is not a common practice in western Oromia. Besides, due to the relatively higher availability of firewood, unlike the central and eastern highlands, FYM is not used for fuel in the region. These and the low rates of NP fertilizers currently being used for maize production under farmers' conditions have aggravated the situation of soil fertility degradation and declining maize production. Consequently, training the farming community on the proper handling and use of FYM together with low rates of inorganic fertilizers could be one alternative solution for the resource poor farmers in the region. The objective of this study was to introduce the culture of integrating FYM and NP fertilizers for maize production in western Oromia.

MATERIALS AND METHODS

Description of the study area

The study sites are located in East Wollega Zone of Oromia National Regional State, western Ethiopia, in the sub humid agro-ecology of the country at 260 km west of Addis Ababa. The locations lie within a 30 km radius of 9º6' N latitude and 37º 9' E longitude with altitude range of 1650-2000 m.a.s.l. Long-term weather data (1961-2001) at the Bako Agricultural Research Center indicates that the study area has a unimodal rainfall pattern and average annual total rainfall of 1244 mm. The rainy season occurs during April to December and maximum rain is received in the months of June, July and August. The minimum, maximum and average air temperature is 14.1º, 27.9º and 20.6ºC, respectively. The average soil temperature at 1-m soil depth is 24ºC (Zewude, personal communication). The dominant soil type in the study area is Alfisols with clayey texture, acidic reaction, low total N, organic carbon, and available P (Wakene, 2001).

Sampling and laboratory analysis of soils and farmyard manure

Composite soil samples were collected from the plow layers at each experimental site before applications of the treatments in 1997 and from the plots that received 12 t FYM ha^{-1}, 60/30 N/P kg ha^{-1} and 60/30 N/P kg ha^{-1} plus 12 t ha^{-1} of FYM at the end of the experiment in 1999. Standard laboratory procedures for each parameter were followed in analyzing the composite surface soil samples and the FYM. Determination of soil particle size distribution was carried out using the hydrometer method. Soil pH was measured potentiometrically using digital pH meter in 1:2.5 soil to solution ratio with H2O and 1 M KCl solution.

Exchangeable bases were extracted with 1.0 M-ammonium acetate at pH 7 for both soil and FYM samples. Ca and Mg in the extract were measured by atomic adsorption spectrophotometry while K and Na were determined using flame photometry. Cation exchange capacity (CEC) of the soil was determined with the ammonium acetate saturated samples using Na from percolating NaCl solution to replace the ammonium ions. The displaced ammonium was measured using the modified Kjeldahl procedure (Chapman, 1965) and reported as CEC. Percent base saturation was calculated from the sum of exchangeable bases as a percent of the CEC of the soil. Exchangeable acidity was determined by extracting the soil samples with M KCl solution and titrating with sodium hydroxide as described by McLean (1965).

Organic carbon was determined following the wet digestion method as described by Walkley and Black (1934). Total N in both soils and compost was determined by the Kjeldahl procedure as described by Jackson (1958). Available P in the soil samples was determined by the Olsen (Olsen et al., 1954) and Bray II (Bray and Kurtz, 1945) methods whereas only the Bray II method was used for available P in compost. Total P in the FYM was extracted using aqua regia digestion technique. The P different extracts was measured by spectrophotometer following the procedure described by Murphy and Riley (1962). Available Fe, Mn, Zn and Cu in the composts were extracted with DTPA as described by Lindsay and Norvell (1978) and were measured by atomic absorption spectrophotometry.

Treatments and experimental design

The experiment was conducted during the 1997 and 1998 cropping cropping seasons in five locations (Shoboka, Laga Kalla, Walda, Harato, and Bako Agricultural Research Center) in the maize-based farming system of western Oromia. The treatments used were 0/0, 20/20, 40/25, and 60/30 kg N/P ha^{-1} and 0, 4, 8 and 12 t FYM ha^{-1} in factorial arrangement using the BH-660 hybrid maize. Treatments were laid out in arandomized complete block design with three replications.

The FYM used for the experiment was well decomposed under shade and applied all at planting in spots with P fertilizer; N fertilizer was applied in split form with half of the dose applied at planting and the remaining half at 30 to 40 days after planting. The residual effects of FYM on maize grain yields at Shoboka, Laga Kalla and Walda were evaluated during the 1998 cropping season. All the necessary cultural practices recommended to the hybrid maize production were used for the management of the experimental plots throughout the cropping seasons. The farmers with the close supervision of the technical assistants and researchers managed the experimental fields. The yield data were subjected to statistical analysis using MSTATC computer software and the least significant difference (LSD) was used to separate significant treatment means.

Table 3. Elemental composition of the FYM used as organic fertilizer in the experiment

A) Nutrient Element Composition of the FYM

Nutrient (FYM)	Total N (%)	Total P (mg kg^{-1})	Available nutrient content (mg kg^{-1})					Exchangeable bases (cmol$_c$kg^{-1})			
			Bray-II P	Fe	Mn	Zn	Cu	Na	K	Ca	Mg
	2.34	6780	427	31	145	29	3.5	0.88	17.12	15.26	15.74

B) Quantity of nutrient (kg) in the 4, 8 and 12 t ha^{-1} of Applied FYM

FYM, t	Total N	Total P	Bray-II P	Fe	Mn	Zn	Cu	Na	K	Ca	Mg
4	94	27	1.7	0.13	0.58	0.12	0.01	0.8	27	12	8
8	187	54	3.4	0.26	1.16	0.24	0.03	1.6	54	24	15
12	281	81	5.1	0.39	1.74	0.36	0.04	2.4	80	37	23

Table 4. Main effects of FYM and NP fertilizers on maize grain yield (t ha^{-1}) during the 1997 cropping season

Main effect	BRC	Walda	Shoboka	Harato	Laga Kalla	Mean
N/P (kg ha^{-1})		(t maize grain ha^{-1})				
0/0	3.61 c	6.14	6.08 b	6.51 b	3.70 b	5.21 c
20/20	5.37 b	6.69	7.16 a	7.35 ab	4.28 b	6.17 b
40/25	5.32 b	6.67	7.44 a	7.35 ab	5.06 a	6.37 b
60/30	6.09 a	6.97	7.12 a	8.07 a	5.54 a	6.76 a
LSD(.05)	0.62	NS	0.91	NS	0.66	0.36
FYM (t ha^{-1})						
0	3.38 c	6.00	6.13	7.19	4.03 b	5.35 c
4	4.78 b	6.71	7.43	7.29	4.24 b	6.09 b
8	6.18 a	6.97	7.12	7.40	5.07 a	6.55 a
12	6.05 a	6.79	7.14	7.41	5.24 a	6.53 a
LSD(.05)	0.62	NS	0.91	NS	0.66	0.36
CV (%)	14.5	16.9	15.6	16.6	17.1	16.4

Bako Research Center, means within a column followed by the same letter(s) are not significantly different at 0.05 levels

RESULTS AND DISCUSSION

Soil physical and chemical properties

Laboratory analytical results of selected physicochemical properties of the soils on which these on-farm experiments were conducted are presented in Tables 1 & 2. Soils in the study areas are dominantly clay loams while some are loamy in texture and vary from medium to moderately acidic based on pH (H_2O). The use of acid forming inorganic fertilizers in the region could lead to soil acidity constraints in the weakly buffered Alfisols.

Based on criteria defined by Landon (1991), the soil organic carbon contents at all locations are low whereas total N was medium except for the Bako Agricultural Research field, indicating the low fertility status of the soils. This could be due to the high temperature, continuous cultivation, and lack of incorporation of organic materials into the soils.

The cation exchange capacity of the soils ranged from 15.0 $cmol_c\ kg^{-1}$ at the Bako Agricultural Research Center to 37.2 $cmol_c\ kg^{-1}$ at Shoboka (Table 2). Exchangeable bases at all sites were sufficient for crop production, although the lowest was recorded in the soil of the Research Center. This could be attributed to the cropping history of the Center, which is quite different from that of the farmers' fields. In both the farmers' fields and the research station, available P (Olsen and Bray II extractable P) was deficient. In general, the low available soil P is presumably attributed to the high P fixing capacity of the Alfisols in these areas. In line with this, Wakene (2001) reported results indicating considerable fixation of available P by Al, Fe, and Ca in Alfisols of the same region.

Chemical composition of farmyard manure

The chemical composition of the FYM used in the field experiments is shown in Table 3a. The FYM contained considerable amounts of essential macronutrients and small amounts of micronutrients. In terms of total nutrients applied per hectare (see Table 3b), 4 t-FYM ha^{-1} supplied 85% of the recommended fertilizer N rate (110 kg ha^{-1})and 136% of the recommended fertilizer P rate (20 kg ha^{-1}) as well as asubstantial proportion of the maize crops K and Mg requirements. However, not all of the total N and P are immediately available for crop uptake. In terms of available P, 4 t FYM ha^{-1} supplied only 9% of the recommended P rate from inorganic fertilizer; 12 t FYM ha^{-1} thus supplied only 26% of the requisite available P. However, much of the P in unavailable forms is expected to become slowly available both during the current growing season to the crop to which it is applied as well as to subsequent crops through residual effects. The FYM supplied the soil with rather minor amounts of the micronutrients, in each case never more than 1 kg nutrient ha^{-1} (Table 3b). Thus, FYM is a source of most essential plant nutrients and, hence, is a complete fertilizer for sustaining production of maize and other crops provided that other abiotic and biotic factors are favorable. Moreover, FYM application helps to maintain soil organic matter content and soil biological activity. In other words, the application of FYM continuously could improve the soil physicochemical properties and sustain production and productivity.

In the present study, the application of FYM alone or with low rates of NP fertilizers did not bring about significant changes on the selected soil properties. This may be due to the treatments were spot applied to feed the crop, not to feed the soils. Soil sampling did not target the spot application points.

Maize grain yield

The grain yields of maize produced under different integrated rates of FYM and NP fertilizers at five locations in western Oromia are presented in Tables 4, 5, 6 and 7. Maize grain yields at all locations in 1997 cropping season were significant ($p \leq 0.05$) affected by both applied FYM and NP fertilizers except for Walda and Harato (Table 4). Except for Shoboka, interactions between FYM and NP fertilizers on maize grain yield were also significant ($p \leq 0.05$) (Table 5). The combined statistical analysis over locations also revealed significant main effects of FYM and NP fertilizers ($p \leq 0.05$) and interactions between these factors (Tables 4 and 5).

The average grain yield of maize increased consistently with increasing rates of NP fertilizers and FYM. Yields of control plots ranged from <1.0 t ha-1 at BRC to almost 6.0 t ha-1 farmers' fields at Harato (Table 5), indicating a fairly

Table 5. The effects of FYM and NP fertilizers on maize grain yield at five locations in the 1997 cropping season

N/P	+ FYM	BRC	Walda	Shoboka	Harato	Laga Kalla	Mean
(kg ha^{-1}	+ t ha^{-1})			(t maize grain ha^{-1})			
0/0	+ 0	0.90 h	4.68 c	4.44	5.79 d	1.86 f	3.53 g
0/0	+ 4	3.61 g	6.68 ab	6.43	7.72 abcd	4.37 cde	5.76 ef
0/0	+ 8	4.87 cdef	6.50 abc	6.52	5.74 d	4.41 cde	5.61 f
0/0	+ 12	5.05 cde	6.71 ab	6.95	6.78 d	4.17 de	5.93 def
20/20	+ 0	3.79 fg	6.70 ab	6.88	6.20 d	4.75 bcd	5.66 ef
20/20	+ 4	4.69 defg	7.44 ab	7.82	6.96 cd	3.27 e	6.04 def
20/20	+ 8	6.50 ab	6.88 ab	7.44	8.94 abc	4.35 de	6.82 bc
20/20	+ 12	6.50 ab	5.76 bc	6.52	7.28 bcd	4.75 bcd	6.16 cdef
40/25	+ 0	4.33 efg	6.12 abc	6.70	9.06 ab	4.46 cde	6.13 cdef
40/25	+ 4	5.05 cde	5.71 bc	8.00	6.78 d	4.66 bcd	6.04 def
40/25	+ 8	5.96 bc	7.98 a	7.64	7.57 abcd	5.67 abc	6.96 ab
40/25	+ 12	5.96 bc	6.88 ab	7.44	6.00 d	5.44 abcd	6.34 bcde
60/30	+ 0	4.51 efg	6.52 abc	6.52	7.68 abcd	5.04 bcd	6.06 def
60/30	+ 4	5.77 bcd	7.05 ab	7.47	7.68 abcd	4.67 bcd	6.53 bcd
60/30	+ 8	7.40 a	6.52 abc	6.88	7.34 bcd	5.85 ab	6.80 bc
60/30	+ 12	6.78 ab	7.80 a	7.64	9.58 a	6.61 a	7.68 a
LSD (5%)		1.24	1.86	NS	2.02	1.32	0.72
CV (%)		14.54	16.87	24.00	16.59	17.05	16.45

BRC = Bako Research Center, means within a column followed by the same letter(s) are not significantly different at 0.05 level

high level of soil fertility at some sites. This could be due to the differences in cropping history, cropping systems, land management and variations in socio-economic circumstances among the farmers. For instance, the host farmer from Walda was educated to a certain level, and knows the consequences of soil degradation on crop productivity. At Harato monoculture of maize is not commonly practiced; farmers are accustomed to growing diversified crops which help to maintain soil fertility.

No significant response to NP or FYM was observed at Shoboka. At Walda, Harato and Laga Kalla, the first 4 t ha^{-1} increment FYM alone was generally sufficient to achieve maximum maize yield; only at BRC did maize respond to higher rates of FYM without NP fertilizer application (Table 5). Similarly, there was generally no significant response to increasing rates of NP fertilizer alone beyond the first increment of 20/20 kg NP ha^{-1}. At the least fertile (most responsive) sites, maximum yield was only obtained with combined application of NP fertilizer (sub-optimal levels) and FYM. This implies that nutrients (especially N and P) in FYM are not immediately available during the season of application to fully nourish a maize crop even though the total quantities applied were in excess of recommended requirements based on inorganic NP fertilizer rates. Low sub-optimal rates of NP fertilizers alone were as effective as high rates of N and P from heavy FYM applications. Under conditions of low soil fertility, combined application of NP fertilizer and FYM are most effective because the supply of nutrients from both sources is additive (Paustian et al., 1992). Moreover, a readily available supply of N and P from fertilizer may enhance mineralization of unavailable organic N and P forms supplied in FYM providing a synergy in which the whole is greater than the sum of the parts.

There were significant main effects on grain yield in 1998 of NP fertilizer and FYM residues applied in 1997 at two of the three sites observed (Table 6). NP fertilizers showed significant residual effects ($p<0.05$) on grain yield at Walda and Shoboka whereas FYM produced significant residual effects on grain yield at Shoboka and Laga Kalla (Table 6). However, interactions of the residues of NP fertilizers and FYM on maize grain yield were not significant at any site (Table 7).

Table 6. Main effects of FYM and NP fertilizer residues applied in 1997 on maize grain yield in the 1998.

Main effect	Walda	Shoboka	Laga Kalla	Mean
N/P (kg ha^{-1})		(t maize grain ha^{-1})		
0/0	5.82 b	3.31 c	4.35	4.49 b
20/20	6.81 a	4.48 b	4.67	5.32 a
40/25	6.77 a	5.18 ab	4.95	5.63 a
60/30	6.86 a	5.64 a	4.30	5.60 a
LSD(.05)	0.78	0.92	NS	0.47
FYM (t ha^{-1})				
0	6.45	3.64 c	3.88 c	4.66 c
4	6.36	4.85 ab	4.25 bc	5.15 b
8	6.41	4.38 bc	4.95 ab	5.25 b
12	7.04	5.74 a	5.19 a	5.99 a
LSD(.05)	NS	0.92	0.80	0.47
CV (%)	14.27	23.67	21.06	19.05

Means within a column followed by the same letter(s) are not significantly different at 0.05 probability level

Table 7. Interactions of FYM and NP fertilizer residues applied in 1997 on maize grain yield in the 1998.

N/P	+ FYM	Walda	Shoboka	Laga Kalla	Mean
(kg ha^{-1}	+ t ha^{-1})		(t maize grain ha^{-1})		
0/0	+ 0	5.05	2.24	2.99	3.43
0/0	+ 4	5.41	3.54	3.74	4.23
0/0	+ 8	6.32	2.61	4.67	4.53
0/0	+ 12	6.50	4.85	5.98	5.78
20/20	+ 0	7.04	3.36	4.67	5.02
20/20	+ 4	6.68	4.29	4.11	5.03
20/20	+ 8	6.86	5.04	5.05	5.65
20/20	+ 12	6.68	5.22	4.86	5.59
40/25	+ 0	7.04	4.48	4.11	5.21
40/25	+ 4	7.04	5.97	5.42	6.14
40/25	+ 8	6.14	4.29	5.24	5.22
40/25	+ 12	6.86	5.97	5.05	5.96
60/30	+ 0	6.68	4.48	3.74	4.97
60/30	+ 4	6.32	6.00	3.74	5.35
60/30	+ 8	6.32	6.00	4.86	5.73
60/30	+ 12	8.12	6.90	4.86	6.63
LSD (.05)		NS	NS	NS	NS
CV (%)		14.27	24.00	21.00	19.05

Means within a column followed by the same letter(s) are not significantly different at 0.05 level

In agreement with the results of this study, various other studies have also shown the importance of organic nutrient sources particularly when integrated with mineral fertilizers in improving crop yields and land productivity under Ethiopian conditions (Asfaw et al., 1997; Asfaw et al., 1998; Heluf et al., 1999; Heluf, 2002). The findings of the present study indicate that the potential of FYM or organics improves when used together with mineral fertilizers. It has similarly been found that the use of crop residues with freshly applied and with residual NP fertilizers has significant effects on maize grain yields under Ethiopian conditions. Generally, the wide gaps between the grain yields of maize produced on the control plots and on the treatments supplied with FYM alone or together with NP fertilizers across locations and cropping seasons in this study is expected to attract the attention of the farmers and help them to have a better understanding about the value of FYM in sustaining maize production.

CONCLUSIONS

According to the study, the integrated use of various rates of FYM and low rates of N/P fertilizers are better than the application of either NP fertilizers or FYM alone. However, the sole application of FYM at the rates of 4-12 t ha^{-1} is also encouraging for resource poor farmers on relatively fertile soils like Walda and Harato areas. As indicated in its chemical composition, the applied FYM supplied the crop with considerable amounts of different essential macronutrients and small amounts of micronutrients usually deficient in acid soils. However, in this study, the FYM was applied in spots with the maize seed with the intention to feed the crop. Therefore, it is not expected to bring significant change on soil physicochemical properties after crop harvest. As a long-term strategy in the future, locally available sources of organic fertilizers should be used on a continuous basis for replenishing the degraded physicochemical properties of the soils in the region.

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