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Integrated Use of 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 system 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 ($p \leq 0.05$) 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 in 1997. There were significant residual effects of FYM and NP fertilizers applied in 1997 on maize grain yields in 1998. Laboratory analysis confirmed that considerable amounts of macronutrients and small amounts of micronutrients were supplied by FYM. 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 fertility and are encouraging for resource poor farmers.

Keywords: farmyard manure, integrated nutrient management, NP fertilizers, residual effects, Ethiopia

1 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

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where fertilizer use is low and little or no agricultural residues are returned to the soil for maintaining soil fertility. Alfisol is the dominant soil type in the region. This soil is characterized by low cation exchange capacity (CEC), and low contents of organic matter, available phosphorus (P) and total nitrogen (N) (ASFAW NEGASSA *et al.*, 1997; WAKENE NEGASSA, 2001). Several natural and socioeconomic factors are 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 low rate 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 used by some farmers but when the fertilizer subsidy was removed 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 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 DADHI *et al.*, 1987). There exists a large volume of literature reporting 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 (INCKEL *et al.*, 1996; ASFAW BELAY *et al.*, 1997, 1998). For instance 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 and TEMU, 1992).

Despite the high number of cattle per household and the availability of cheap family labor that could be used for FYM collection, incubation and transportation, the use of FYM for soil fertility maintenance is limited to homestead. Besides, due to the relatively higher availability of firewood, unlike the central and eastern highlands of Ethiopia, 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 fertility management. The objective of this study was to introduce the culture of integrating FYM and NP fertilizers for maize production in western Oromia.

2 Materials and Methods

2.1 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 260-290 km west of Addis Ababa. The locations lie within a 30 km radius of 9° 6' N latitude and 37° 9' E longitude with altitude range of 1650-2000 m.a.s.l. Long-term weather data (1961-2001) at the Bako Research Center (BRC) indicate 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 14.1°, 27.9° and 20.6 °C, respectively. The average soil temperature at 1-m soil depth is 24°C (Zewude, personal communication). The dominant soil type in the study area is Alfisol with clayey texture, acidic reaction, low total N, organic carbon, and available P (Wakene Negassa, 2001).

2.2 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 1998. 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 H_2O and 1 M KCl solution. Exchangeable bases were extracted with 1.0 M-ammonium acetate at pH 7 and were measured by atomic adsorption spectrophotometry. Cation exchange capacity (CEC) of the soil was determined with the ammonium acetate saturated method (Chapman, 1965). Exchangeable acidity was determined by extracting the samples with 1 M KCl solution and titrating with NaOH as described by McLean (1965). Organic carbon was determined following the wet digestion method as described by Walkley and Black (1934). Total N 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 DTP A as described by Lindsay and Norvell (1978) and were measured by atomic absorption spectrophotometry.

2.3 Treatments and Experimental Design

The experiment was conducted during the 1997 and 1998 cropping seasons in five locations (Shoboka, Laga Kalla, Walda, Harato and BRC) in the maize-based farming system of western Oromia. The treatments used were 0/0, 20/20, 40/25, and 60/30 kg N/Pha^{-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 a randomized 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

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 (kg+t ha^{-1})*	*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
	98	0/0 + 12	5.17	3.99	2.15	0.18	40	31	29	CL	4.18	5.20
	98	60/30 + 0	5.05	3.67	1.56	0.13	33	29	28	CL	9.48	10.12
	98	60/30 + 12	5.65	4.30	1.88	0.14	38	25	27	SCL	7.62	8.33
	97	0/0 + 0	5.30	4.04	2.57	0.22	29	37	34	CL	3.06	2.80
	98	0/0 + 12	5.05	4.00	1.76	0.14	30	36	34	CL	4.21	6.71
Shoboka	98	60/30 + 0	5.20	4.12	1.76	0.13	31	37	32	CL	3.86	4.20
	98	60/30 + 12	5.42	4.20	2.35	0.23	29	38	23	L	3.10	4.21
	97	0/0 + 0	5.25	4.35	2.17	0.20	39	33	28	CL	3.86	4.50
	98	0/0 + 12	5.73	4.24	2.87	0.26	40	32	28	CL	4.46	12.41
Laga Qalla	98	60/30 + 0	5.71	4.42	2.85	0.24	38	36	26	L	7.64	7.26
	98	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, Yr = year, 97 = 1997 = soil samples collected before treatments application, 98= 1998 = soil samples= taken after treatments application

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.

3 Results and Discussion

3.1 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. The use of acid forming inorganic fertilizers in the region could lead to soil acidity constraints in the weakly buffered Alfisol. 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 BRC, indicating the low fertility status of the soils. This could be due to 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 BRC to 37.2 cmol$_c$ kg^{-1} at Shoboka (Table 2). The 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,

Table 2: 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* (*kg + t* ha^{-1})	*Exchangeable bases, acid and CEC* ($cmol_c kg^{-1}$)							*PBS* (%)
			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
	98	0/0 + 12	0.63	1.38	4.99	1.33	0.45	Tr.	25.2	33
	98	60/30 + 0	0.39	0.72	2.94	0.83	0.36	Tr.	15.0	40
	98	60/30 + 12	0.79	1.99	3.79	1.25	0.52	Tr.	19.4	62
	97	0/0 + 0	0.38	1.23	15.0	6.50	0.12	Tr.	37.2	62
	98	0/0 + 12	0.39	0.59	4.14	1.08	0.32	Tr.	20.2	31
Shoboka	98	60/30 + 0	0.47	0.87	3.99	1.00	0.51	Tr.	21.0	30
	98	60/30 + 12	0.55	1.28	7.88	2.50	0.40	Tr.	33.8	36
	97	0/0 + 0	0.31	1.91	4.69	2.08	0.16	Tr.	23.2	30
	98	0/0 + 12	0.87	2.32	7.83	1.83	0.23	Tr.	31.4	39
Laga Qalla	98	60/30 + 0	0.63	1.79	8.78	2.08	0.12	Tr.	30.6	31
	98	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, 98 = 1998 = soil samples taken after treatments application, Tr = trace

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 NEGASSA (2001) reported results indicating considerable fixation of available P by Al and Fe in Alfisol of the same region.

3.2 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), the FYM supplied high amount of total N as well as substantial 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.

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

A) Nutrient element composition of the FYM

Total N (%)	Total P (%)	*Available nutrient content* (mgkg^{-1})					*Exchangeable bases* (cmol$_c$kg^{-1})			
		P (Bray-II)	Fe	Mn	Zn	Cu	Na	K	Ca	Mg
2.34	0.678	427	31	145	29	3.5	0.88	17.1	15.3	15.7

B) Nutrient quantity (kg) in 4,8 and 12 t ha^{-1} *of the applied FYM*

FYM (t)	Total N	Total P	P (Bray-II)	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

3.3 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, and 6. Maize grain yields at all locations in the 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} on farmers' fields at Harato (Table 5), indicating a fairly 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

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

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

* BRC: Bako Research Center

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 (data not presented). In agreement

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

N/P + *FYM* (*kg* ha^{-1}+ *t* ha^{-1})	*t maize grain* ha^{-1}					
	*BRC**	*Walda*	*Shoboka*	*Harato*	*Laga Kalla*	*Mean*
0/0 + 0	0.90^{h}	4.68^{e}	4.44	5.79^{d}	1.86^{f}	3.53^{g}
0/0 + 4	3.61^{g}	6.68^{ab}	6.43	7.72^{abed}	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 the 0.05 level

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 Belay *et al.*, 1997, 1998; Heluf Gebrekidan *et al.*, 1999).

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 are 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.

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

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

4 Conclusions

According to the study, the integrated use of various rates of FYM and low rates of NIP 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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