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Combined Application of Organic and Inorganic Fertilizers to Increase Yield of Barley and Improve Soil Properties at Fereze, In Southern Ethiopia

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Abstract

Integrated nutrient management, where both natural and man-made sources of plant nutrients are used, is the best approach to supply adequate and balanced nutrients and increase crop productivity in an efficient and environmentally benign manner, without sacrificing soil productivity of future generations. The objective of this study was thus, to investigate the effect of organic and inorganic fertilizers on soil properties and yield of barley. Three levels of FYM (0, 10 t/ha, and 20 t/ha) were combined in factorial experiment with different rates of inorganic NP (46, 40; 23, 20) and NPK (0, 0,0; 46, 40, 50; 23, 20, 25) and laid down in RCBD design with three replications. The experiment was conducted for three consecutive years without changing plots that received FYM only in the first year but received inorganic fertilizers every year (every cropping season). DAP was used as source of N and P, Urea was used as another source of N, and KCl was used as source of K. FYM was incorporated in to the soil one month before planting the barley. All doses of P and K were applied during planting but N was applied in two splits-half at planting and another half when the plant acquires 10 cm height (at one month age). Crop data such as plant height, biomass yield and grain yield were collected and analyzed using the SAS computer software program. Surface soil samples (0-30 cm) were collected before planting (composite sample) and after harvesting from each treatment and analyzed for the required parameters using standard laboratory procedures. Application of both types and all amounts of fertilizers significantly increased barley production at Fereze. The highest barley production was obtained from application of 46 kg N + 40 kg P + 50 kg K and 20 t/ha FYM, whereas the lowest barley production was obtained from the control (the non-fertilized) treatment. The highest grain yield obtained was 4895.8 kg/ha (around 49 qt/ha), whereas the lowest was 1750 kg/ha (17.5 qt/ha). About 31 qt/ha yield advantage was obtained due to application of 46 kg N + 40 kg P + 50 kg K and 20 t/ha FYM as compared to the control treatment. On the other hand, grain yield advantage of 7.5 to 9.2 qt/ha was obtained due to the application of only FYM over the control treatment. Again, 21.5 qt/ha of grain yield advantage was obtained due to the application of only NPK over the control treatment. Grain yield advantage of 13 qt/ha was obtained due to application of only half rate of NPK (23/20/25 kg/ha of N/P/K, respectively). Both 10 t/ha and 20 t/ha FYM significantly increased barley production as compared to the control treatment. Integrated application of inorganic fertilizers (NP or NPK) with FYM gave a better result than application of inorganic fertilizers alone. Therefore, integrated application of inorganic fertilizers with organic fertilizers (FYM) is a better approach to increase barley yield than application of either inorganic or organic fertilizers alone.

Keywords: FYM, NPK, Integrated nutrient management, NP

Background and justification

Declining soil fertility and management of plant nutrients aggravate the challenge of agriculture to meet the world's increasing demand for food in a sustainable way. Nitrogen and phosphorus deficiencies are widespread in all Sub-Saharan Africa agro-ecosystems, with 80% of the soils deficient in P (CIAT, 2006). Harsh climatic conditions, population pressure, land constraints, and the decline of traditional soil management practices have often reduced soil fertility in developing countries (Gruhn *et al.,* 2000). In mid and high altitude areas, where rainfall is higher, soil acidification due to leaching of basic cations (Ca, mg, K and Na) also contributes a lot to soil fertility declining (Whitney and Lamond, 1993). Continuous cropping and erosion reduce the level of soil organic matter in densely populated mid and high-altitude areas. Unless soil management practices are improved, yield reduction continues and long-term production is difficult. The low level of chemical fertilizer use, decline in soil organic matter, and insufficient studies contribute the most to the loss of soil fertility in Sub-Saharan Africa. Soil organic matter helps sustain soil fertility by improving retention of mineral nutrients, increasing of the water-holding capacity of soils, increasing the amount of soil flora and fauna, improves air circulation and drainage.

An adequate supply of plant nutrients is essential for efficient crop production on the highly weathered and leached soils of the humid tropics. As most soils of the humid tropics are deficient in primary nutrients particularly N and P, it is necessary to supply nutrients from external sources.

Soil organic matter content can be increased by applying organic fertilizers such as animal manure (farm yard manure). Livestock manure is rich in plant nutrients containing 70-80 % of the nitrogen (N), 60-85 % of the phosphate (P_2O_5), and 80 % of the potassium (K_2O) fed to animals. In addition to supplying nutrients, organic fertilizers are considered to be one of the best measures to reclaim soil acidity (Chen *et al.,* 2001) and they improve soil fertility by favourable chemical and physical attributes to the soil (Gaskel et al., 2007). The same authors indicated that application of composted livestock manure on strongly acidic soils increased availability of N and P and improved soil productivity. However, very large amounts of organic fertilizers must be applied, as they are dilute source of nutrients compared to inorganic fertilizers. Besides, nutrients in organic fertilizers are released much more slowly than synthetically produced ones and cannot increase crop yield within short time as compared to inorganic fertilizers.

The use of chemical fertilizers is essential for obtaining high yields in the weathered soils of the humid tropics and can overcome the shortcomings of organic fertilizers. However, many small holders and resource poor farmers cannot afford costly fertilizers to apply the recommended amount. In addition to this, the inorganic fertilizers available in Ethiopia do not replace trace mineral elements in the soil, which become gradually depleted by crops removal and cannot maintain desirable soil physical properties such as water holding capacity and congenial conditions for microbial activity (Kumar and Sreenivasulu, 2004).

To ensure soil productivity, plants must have an adequate and balanced supply of nutrients that can be realized through integrated nutrient management where both natural and man-made sources of plant nutrients are used (Gruhn *et al.,* 2000). Chemical fertilizers stimulate the availability of nutrients in organic manures (Kumar and Sreenivasulu, 2004). Chen *et al. (2001*) indicated that supplementing composted livestock manure and nutrient rich trees/shrubs and legumes with added inorganic fertilizers makes the compost in to a more complete nutrient source for strongly acidic soils.

Therefore, the use of integrated nutrient management is very important and best approach to maintain and improve soil fertility (Lander et al., 1998) thereby to increase crop productivity in an efficient and environmentally benign manner, without sacrificing soil productivity of future generations. This study was conducted with the objective of investigating the effect of organic and inorganic fertilizers on yield of barley and chemical properties of soil.

Materials and Methods

The experiment was conducted in 2007, 2008 and 2009 cropping seasons at Fereze research sub-center in Gurage zone. The organic fertilizer (farm yard manure) was applied only once and plots were maintained for residual effect until the experiment was completed, but inorganic fertilizers were applied at each cropping season. The treatments comprised 0, the recommended rate and half of the recommended rate of NP with the interaction of 0, 10 and 20 t/ha farm yard manure (FYM). The farmyard manure was composted in a pit for a month and applied to the experimental field one month before planting. Forty surface (0-30 cm) soil samples were collected in a zigzag way and composited before planting. At harvest, 10 surface soil samples per plot were collected and composited for each plot. Urea, TSP and KCl were used as sources of N, P and K, respectively. Nitrogen was applied in split half at planting and half at 10 cm height. All dose of P was applied at once at planting time. Laboratory analysis was carried out following the standard procedure developed for each parameter.

Results and Discussion

Application of farm yard manure (FYM) significantly influenced plant height, biomass and grain yields (here after referred as barley production) at Fereze (Tables 1, 2 and 3). Both 10 t/ha and 20 t/ha FYM significantly increased barley production as compared to the control treatment (the treatment with no fertilizer). But there is no significant difference in barley production between the application of 10 t/ha and 20 t/ha. Application of the FYM significantly increased barley production in the first year. An experiment conducted on maize and wheat in China indicated that application of organic manure alone supplied some nutrients and gave higher yields than the non-fertilized ones although it was not sufficient to support a high yield. On the other hand, the treatments that received complete nutrients (NPK) gave highest yield for both wheat and maize crops (Jiyun and Zhang, 1995).

Application of NPK fertilizers gave higher barley production than application of NP alone, although not significant. Application of 46/40/50 kg N/P/K/ha (here after referred as full rate of NPK) gave better result (barley production) than application of 46/40 kg N/P/ha (here after referred as full rate of NP). Application of inorganic fertilizers (NP or NPK) with FYM gave a better result than application of inorganic fertilizers alone. But the best result was obtained when NPK was applied with FYM rather than when NP was applied with FYM. Barley production was increased with increasing application of FYM be it alone or integrated with inorganic fertilizer. Application of NP integrated with FYM gave higher result than application of NPK alone. This indicates that application of FYM is more important than application of K which might be attributed to the beneficial effects of FYM (organic fertilizer) on the soil's physical, chemical and microbiological properties of soil (Chong, 2005). Application of only half amount of 46/40/50 kg/ha of N/P/K (here after referred as half rate of NPK), respectively, gave significantly lower results in all parameters than the full rate of the inorganic fertilizer. However, application of the full rate of NPK alone did not significantly increase barley production over the half rate of NPK when applied with FYM (10 t/ha and 20 t/ha). Of course, the full rate of NPK alone gave a better result than the half rate of NPK applied with FYM, although not significant. Nevertheless, application of half rate of NPK with or without FYM gave significantly lower result than application of the full NPK integrated with FYM.

Application of both types and all amounts of fertilizers significantly increased barley production at Fereze. The highest barley production was obtained from application of full rate of NPK and 20 t/ha FYM, whereas the lowest barley production was obtained from the control (the non-fertilized) treatment. The highest grain yield obtained was 4895.8 kg/ha (around 49 qt/ha), whereas the lowest was 1750 kg/ha (17.5 qt/ha). About 31 qt/ha yield advantage was obtained due to application of the full rate of NPK and 20 t/ha FYM as compared to the control treatment. On the other hand, grain yield advantage of 7.5 to 9.2 qt/ha was obtained due to the application of only FYM over the control treatment. Again, 21.5 qt/ha of grain yield advantage was obtained due to the application of only NPK over the control treatment. Grain yield advantage of 13 qt/ha was obtained due to application of only half rate of NPK (23/20/25 kg/ha of N/P/K, respectively).

The increased production of barley due to the integration of FYM with inorganic fertilizers was due to the addition of nutrients from the FYM, which indicates the full rate of NPK is not enough for barley production at Fereze and additional fertilizers are required (Tables 5 and 6).

There was no significant difference in barley production in the second year due to the first year FYM application (Table 3) either applied alone or integrated with the full rate and the half rate of inorganic fertilizers. This indicates that application of both 10 t/ha and 20 t/ha FYM did have residual effect for the next year production. Therefore, to have residual effect for the next year production, FYM must be applied in larger quantity or continuously for certain years.

Application of full rate of NPK either alone or integrated with FYM, significantly increased barley production over the half rates and the non-fertilized treatments either with or without FYM. All the non- NPK treatments even if they received FYM, gave the least barley production. The result was consistent in the third year too. The first year FYM application did not cause significant difference in barley production in the third year. Significant barley production was obtained among treatments of FYM, full NPK and half NPK whether applied alone or integrated with FYM. The highest result was obtained from the full NPK treatments. Application of half NPK either alone or integrated with FYM, gave the next barley production. The least result was obtained from the non-NPK treatments whether they received FYM or not. All these show that the first year FYM application did not have significant residual effect in the third year of production although a slight increase in barley production was obtained in the third year due the first year application of FYM.

All treatments with fertilizer be it inorganic, organic or combinations of the two gave higher grain yield than the treatment with no fertilizer, which is in agreement with Luu Hong Man et al (2001), who indicated that application of both 100% organic fertilizer and combination of organic and inorganic fertilizers significantly increased yield over the control. When half NPK was applied integrated with FYM, yield increment was obtained with increasing amount of FYM. However, there is no significant yield increment due to FYM application with the half NPK. Application of full NP gave significantly higher barley yield than application of half NP whether the half NP was applied alone or integrated with different rate of FYM.

First year application of FYM has residual effect in the second and third cropping seasons. Treatments which received FYM in the first cropping season gave higher yield than the control without any fertilizer application in the second and third cropping seasons. However, the yield difference obtained due to the residual effect of FYM is not statistically significant indicating additional nutrient application is required for optimum yield. Therefore, yearly application of farm yard manure is required until the soil builds up nutrients, which is in agreement with Luu Hong Man et al (2001), who indicated that continuous application of organic fertilizer (50%) in combination with 50% recommended dose of inorganic fertilizer was found to be equal in yield of rice in Vietnam as compared to treatment in which 100% of inorganic fertilizer was applied alone and inorganic fertilizer was continuously applied alone. (Gaskell et al., 2007) also indicated that adding Farm yard manure to cultivated soils over time builds soil organic matter and improves the ability of the soil to supply nutrients. According to Chong (2005), application of cattle manure for 20 years resulted in a significant increase in soil P levels (from 9 mg/kg to 1, 200 mg/kg) and nitrate N accumulation, reaching 80-100 mg/kg.

Economic Analysis

The economic analysis indicated that the highest net return (16200 Birr) with marginal rate of return (MRR) of 300 % was obtained by application of 46 kg N + 40 kg P + 50 kg K + 20 t FYM/ha followed by a net return of 15000 Birr with MRR of 252 % by application of 46 kg N + 40 kg P + 20 t FYM/ha (Table 4). The lowest net return (700 Birr) was obtained from the control treatment (non fertilized treatment). Application of 46 kg N + 40 kg P + 50 kg K/ha without FYM and with both rates of FYM (10 t and 20 t/ha) is economical. Application of 23 kg N + 20 kg P + 25kg K/ha without FYM and with 10 t/ha FYM is economical, but not economical with 20 t/ha FYM. The MRR indicated that application of 10 t/ha FYM alone is economical, whereas application of 20 t/ha FYM alone is not economical although a significant yield difference was obtained with application of 20 t/ha FYM as compared to the control.

Application of FYM and integrated nutrient management influenced the chemical properties of soil (Table 5). Both FYM and integrated nutrient management increased available P, total N, soil organic matter (OM), cation exchange capacity (CEC) and calcium (Ca) contents of the soil in all cropping seasons (Table 5, 6 and 7). This is in agreement with Bierman and Carl (2005), who indicated that manure adds nutrients, organic matter and CEC to the soil. Another experiment conducted in Sweden also showed that application of organic fertilizers improved the chemical (pH, P, K, Mg, C and N) and biological properties (Granstedt and Lars, 1997). All the above soil parameters were highest in the first cropping season and decreased in the second and third cropping seasons. However, pH, exchangeable Al and exchangeable K were not that much influenced in all cropping seasons.

Conclusion and recommendation

As the result of both yield and soil analysis indicated the fertility of the soil at Fereze is very low and that is why all treatments with fertilizer (inorganic, organic or combinations of the two) gave higher grain yield than the treatment with no fertilizer, which gave very low yield. Application of FYM has residual effect for the next cropping seasons. Combined application of inorganic and organic (FYM) gave a better result than application of either of one, which indicates integrated nutrient management is the best approach for soil fertility management. Therefore, the use of 46 kg N + 40 kg P + 50 kg K + 20 t FYM/ha can be recommended for better barley production at Fereze.

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Table 1. Mean height of barley plant in meter as influenced by application of FYM + NPK

No.	Treatment	First year (2007)	Second year (2008)	Third year (2009)
1	Control (without fertilizer and FYM)	0.90g	0.89f	0.72c
2	0 kg fertilizer + 10 t FYM/ha	1.06000f	0.94f	0.79c
3	0 kg fertilizer + 20 t FYM/ha	1.0533f	0.90f	0.78c
4	46 kg N + 40 kg P + 50 kg K + 0 t FYM/ha	1.22abcd	1.06ab	1.06a
5	46 kg N + 40 kg P + 50 kg K + 10 t FYM/ha	1.27ab	1.02abcd	1.06a
6	46 kg N + 40 kg P + 50 kg K + 20 t FYM/ha	1.30a	1.07a	1.06a
7	23 kg N + 20 kg P + 25kg K + 0 t FYM/ha	1.07f	1.01abcde	0.95b
8	23 kg N + 20 kg P + 25kg K + 10 t FYM/ha	1.14def	1.00bcde	0.96b
9	23 kg N + 20 kg P + 25kg K + 20 t FYM/ha	1.183cde	0.98cde	0.91b
10	46 kg N + 40 kg P + 0 t FYM/ha	1.17de	1.05abc	1.05a

11	46 kg N + 40 kg P + 10 t FYM/ha	1.26abc	1.04abc	1.04a
12	46 kg N + 40 kg P + 20 t FYM/ha	1.21bcde	1.07a	1.07a
13	23 kg N + 20 kg P + 0 t FYM/ha	1.08f	0.96def	0.95b
14	23 kg N + 20 kg P + 10 t FYM/ha	1.13ef	0.98cde	0.94b
15	23 kg N + 20 kg P + 20 t FYM/ha	1.13ef	0.99bcde	0.91b
	lSD at 5 %	0.088	0.07	0.08
	CV	4.6%	4.22%	5.04%

Means with the same letter are not significantly different

Table 2. Mean biomass yield of barley in kg/ha as influenced by application of FYM + NPK

No.	Treatment	First year (2007)	Second year (2008)	Third year (2009)
1	Control (without fertilizer and FYM)	5500h	2979.2d	3500d
2	0 kg fertilizer + 10 t FYM/ha	8104.2g	3375d	3833.3d
3	0 kg fertilizer + 20 t FYM/ha	8645.8g	2979.2d	3625d
4	46 kg N + 40 kg P + 50 kg K + 0 t FYM/ha	11958.3bc	6750ab	8500ab
5	46 kg N + 40 kg P + 50 kg K + 10 t FYM/ha	13041.7ab	6958ab	8416.7ab
6	46 kg N + 40 kg P + 50 kg K + 20 t FYM/ha	14041.7a	7750a	9291.7a
7	23 kg N + 20 kg P + 25kg K + 0 t FYM/ha	9104.2fg	5354.2b	6104.2c
8	23 kg N + 20 kg P + 25kg K + 10 t FYM/ha	10479.2def	5229.2c	6020.8c
9	23 kg N + 20 kg P + 25kg K + 20 t FYM/ha	11187.5cd	5270.8c	5958.3c
10	46 kg N + 40 kg P + 0 t FYM/ha	11458.3cd	6583.3b	8375ab
11	46 kg N + 40 kg P + 10 t FYM/ha	13208.3ab	7000ab	8270.8ab
12	46 kg N + 40 kg P + 20 t FYM/ha	13479.2a	6520.8b	7604.2b
13	23 kg N + 20 kg P + 0 t FYM/ha	9458.3def	4666.7c	5854.2c
14	23 kg N + 20 kg P + 10 t FYM/ha	10562.5cde	5291.7c	6270.8c
15	23 kg N + 20 kg P + 20 t FYM/ha	10666.7cde	5083.3c	5854.2c
	lSD at 5 %	1427.2	1164.9	1115.4
	CV	4.6%	12.77%	10.26%

Means with the same letter are not significantly different

Table 3. Mean grain yield of barley in kg/ha as influenced by application of FYM + NPK

No.	Treatment	First year (2007)	Second year (2008)	Third year (2009)
1	Control (without fertilizer and FYM)	1750h	1020.8d	875e
2	0 kg fertilizer + 10 t FYM/ha	2500g	1083.3d	979.2e
3	0 kg fertilizer + 20 t FYM/ha	2666.7g	1041.7d	1145.8e
4	46 kg N + 40 kg P + 50 kg K + 0 t FYM/ha	3895.8cd	2562.5ab	2708.3ab
5	46 kg N + 40 kg P + 50 kg K + 10 t FYM/ha	4437.5ab	2604.2ab	2541.7ab
6	46 kg N + 40 kg P + 50 kg K + 20 t FYM/ha	4895.8a	2895.8a	2833.3a
7	23 kg N + 20 kg P + 25kg K + 0 t FYM/ha	3083.3ef	1833.3c	1937.5d
8	23 kg N + 20 kg P + 25kg K + 10 t FYM/ha	3479.2de	1812.5c	1958.3d
9	23 kg N + 20 kg P + 25kg K + 20 t FYM/ha	3833.3cd	1895.8c	2000cd
10	46 kg N + 40 kg P + 0 t FYM/ha	3770.8d	2416.7b	2520.8ab
11	46 kg N + 40 kg P + 10 t FYM/ha	4062.5cd	2604.2ab	2666.7ab
12	46 kg N + 40 kg P + 20 t FYM/ha	4500ab	2437.5b	2354.2bc
13	23 kg N + 20 kg P + 0 t FYM/ha	3125ef	1666.7c	1979.2cd
14	23 kg N + 20 kg P + 10 t FYM/ha	3562.5de	1854.2c	2125cd

15	23 kg N + 20 kg P + 20 t FYM/ha	3500e	1812.5c	1958.3d
	lSD at 5 %	485.13	425.88	381.68
	CV	4.6%	12.93%	11.19%

Means with the same letter are not significantly different

Table 4. Partial budget analysis for the mean grain yield of barley

No	Treatments	Grain yield (kg/ha)	Gross return (Birr)	Total Cost (Birr)	Net return (Birr)	MRR (%)
1	Control (without fertilizer and FYM)	1750	7000	0	700	
2	0 kg fertilizer + 10 t FYM/ha	2500	10000	500	9500	1760
3	0 kg fertilizer + 20 t FYM/ha	2666.7	10640	1000	9640	28
4	46 kg N + 40 kg P + 50 kg K + 0 t FYM/ha	3895.8	15600	2400	13200	254
5	46 kg N + 40 kg P + 50 kg K + 10 t FYM/ha	4437.5	17600	2900	14700	300
6	46 kg N + 40 kg P + 50 kg K + 20 t FYM/ha	4895.8	19600	3400	16200	300
7	23 kg N + 20 kg P + 25kg K + 0 t FYM/ha	3083.3	12320	1200	11120	230
8	23 kg N + 20 kg P + 25kg K + 10 t FYM/ha	3479.2	13880	1700	12180	212
9	23 kg N + 20 kg P + 25kg K + 20 t FYM/ha	3833.3	15200	2200	13000	164
10	46 kg N + 40 kg P + 0 t FYM/ha	3770.8	15080	2000	13080	-0.4
11	46 kg N + 40 kg P + 10 t FYM/ha	4062.5	16240	2500	13740	132
12	46 kg N + 40 kg P + 20 t FYM/ha	4500	18000	3000	15000	252
13	23 kg N + 20 kg P + 0 t FYM/ha	3125	12400	1000	11400	680
14	23 kg N + 20 kg P + 10 t FYM/ha	3562.5	14240	1500	12740	268
15	23 kg N + 20 kg P + 20 t FYM/ha	3500	14000	2000	12000	-148

Price of DAP = 800 birr/qt, Price of Urea = 400 birr/qt, Price of KCl = 800 birr/qt (assumption),
Price of barley = 400 birr/qt, Cost of FYM =5 birr/100 kg , FYM =50 birr/t

Table 5. Chemical properties of soil as influenced by integrated nutrient management in the first cropping season

No	Treatments	pH	Available P olsen (mg/kg)	Total N (%)	OM (%)	CEC (meq/100 g soil)	Ca (cmol/kg)	Ex.K (cmol/kg)	Ex Al (meq/100 g soil)
1	Control (without fertilizer and FYM)	5.6	7.2	0.31	3.17	26.4	9	0.22	0.96
2	0 kg fertilizer + 10 t FYM/ha	5.4	9	0.34	3.06	27.4	10	0.23	0.72
3	0 kg fertilizer + 20 t	5.4	10.8	0.35	3.61	28.4	11	0.26	0.80

	FYM/ha								
4	46 kg N + 40 kg P + 50 kg K + 0 t FYM/ha	5.7	8.6	0.29	3.06	25.8	10	0.24	0.64
5	46 kg N + 40 kg P + 50 kg K + 10 t FYM/ha	5.6	11.4	0.32	3.26	27.2	12	0.24	0.56
6	46 kg N + 40 kg P + 50 kg K + 20 t FYM/ha	5.4	13.2	0.39	3.72	28.6	14	0.23	0.56
7	23 kg N + 20 kg P + 25kg K + 0 t FYM/ha	5.7	5.8	0.29	3.06	31.6	11	0.20	0.40
8	23 kg N + 20 kg P + 25kg K + 10 t FYM/ha	5.4	8	0.31	3.28	32.8	12	0.24	0.64
9	23 kg N + 20 kg P + 25kg K + 20 t FYM/ha	5.5	10.6	0.32	3.58	32.8	13	0.27	0.64
10	46 kg N + 40 kg P + 0 t FYM/ha	5.6	7.4	0.31	3.17	22.4	9	0.23	0.56
11	46 kg N + 40 kg P + 10 t FYM/ha	5.5	8.8	0.32	3.50	27.2	10	0.20	0.80
12	46 kg N + 40 kg P + 20 t FYM/ha	5.5	18	0.35	3.84	31.6	16	0.26	0.72
13	23 kg N + 20 kg P + 0 t FYM/ha	5.4	6.4	0.31	3.17	25.4	9	0.20	0.88
14	23 kg N + 20 kg P + 10 t FYM/ha	5.6	9.6	0.35	3.72	25.4	10	0.22	0.72
15	23 kg N + 20 kg P + 20 t FYM/ha	5.4	10.80	0.37	3.84	25.4	11	0.23	0.72
	Composite sample before fertilizer application	5.1	7.8	0.34	6.72	25.6	9	0.26	0.72

Table 6. Chemical properties soils as influenced by integrated nutrient management in the second cropping season

No	Treatments	pH	P (mg/kg)	Total N (%)	OM (%)	CEC (meq/100 g soil)	Ca (cmol/kg)	K (cmol/kg)	Exchangeable Al (meq/100 g soil)
1	Control (without fertilizer and FYM)	5.4	3.6	0.21	3.28	26.6	14	0.20	1.04
2	0 kg fertilizer + 10 t FYM/ha	5.3	5.2	0.22	3.62	28.6	13	0.23	1.04
3	0 kg fertilizer + 20 t FYM/ha	5.4	6.4	0.34	3.62	28.6	11	0.24	0.96
4	46 kg N + 40 kg P + 50 kg K + 0 t FYM/ha	5.3	6.8	0.28	3.32	25.6	12	0.24	0.56
5	46 kg N + 40 kg P + 50 kg K + 10 t FYM/ha	5.5	9.2	0.30	3.61	28.4	14	0.24	0.32

6	46 kg N + 40 kg P + 50 kg K + 20 t FYM/ha	5.4	11.4	0.35	3.68	29.8	12	0.20	0.22
7	23 kg N + 20 kg P + 25kg K + 0 t FYM/ha	5.4	6	0.27	3.4	23.6	15	0.23	0.88
8	23 kg N + 20 kg P + 25kg K + 10 t FYM/ha	5.8	6	0.28	3.62	28.4	12	0.22	0.80
9	23 kg N + 20 kg P + 25kg K + 20 t FYM/ha	5.4	6.4	0.29	3.96	29.6	12	0.26	0.48
10	46 kg N + 40 kg P + 0 t FYM/ha	5.3	5.6	0.28	3.18	22.4	13	0.19	0.80
11	46 kg N + 40 kg P + 10 t FYM/ha	5.3	8.4	0.29	3.73	25.4	10	0.20	0.48
12	46 kg N + 40 kg P + 20 t FYM/ha	5.5	9	0.31	3.96	26.6	16	0.20	0.56
13	23 kg N + 20 kg P + 0 t FYM/ha	5.7	4.6	0.28	3.18	24.4	14	0.22	0.96
14	23 kg N + 20 kg P + 10 t FYM/ha	5.3	6.8	0.32	3.73	24.4	18	0.19	0.24
15	23 kg N + 20 kg P + 20 t FYM/ha	5.4	9.4	0.34	3.96	25.4	11	0.23	0.88

Table 7. Chemical properties of soil as influenced by integrated nutrient management in the third cropping season

No	Treatments	Available P (mg/kg)	Total N (%)	OM (%)	CEC (meq/100 g soil)	Ca (cmol/kg)	K (cmol/kg)
1	Control (without fertilizer and FYM)	3.2	0.17	3.59	21	11	0.19
2	0 kg fertilizer + 10 t FYM/ha	4.56	0.18	3.9	22	12.5	0.20
3	0 kg fertilizer + 20 t FYM/ha	4.74	0.17	4.2	25	14	0.21
4	46 kg N + 40 kg P + 50 kg K + 0 t FYM/ha	5.63	0.38	3.67	23	13	0.22
5	46 kg N + 40 kg P + 50 kg K + 10 t FYM/ha	7.21	0.17	3.79	25	13	0.23
6	46 kg N + 40 kg P + 50 kg K + 20 t FYM/ha	7.31	0.17	3.83	27	14	0.22
7	23 kg N + 20 kg P + 25kg K + 0 t FYM/ha	7.06	0.17	3.60	22	11.4	0.20
8	23 kg N + 20 kg P + 25kg K + 10 t FYM/ha	5.21	0.38	3.76	25	12	0.22

9	23 kg N + 20 kg P + 25kg K + 20 t FYM/ha	6.05	0.17	3.96	26	13	0.23
10	46 kg N + 40 kg P + 0 t FYM/ha	5.86	0.17	3.62	22	12	0.19
11	46 kg N + 40 kg P + 10 t FYM/ha	5.53	0.18	3.90	24	13	0.20
12	46 kg N + 40 kg P + 20 t FYM/ha	4.79	0.18	3.99	25	14	0.21
13	23 kg N + 20 kg P + 0 t FYM/ha	4.83	0.18	3.6	18	10	0.20
14	23 kg N + 20 kg P + 10 t FYM/ha	4.93	0.18	3.93	21	11	0.22
15	23 kg N + 20 kg P + 20 t FYM/ha	5.11	0.16	4	23	11.5	0.23