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Enhancing Soil Fertility, Maize Grain Yield and Nutrients Composition through Different Planting Time and Manure Sources in Farmers' Fields of Southeastern Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author JCN designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors SON and AON managed the analyses of the study. Author OCO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Maize (*Zea mays* L.) has a good potential as a cereal crop side by side with rice and wheat. Irrespective of its local and industrial uses, the production is still challenged by some factors as environmental changes associated with different sowing date and a decline in soil fertility. A field experiment was conducted at the research farm of the Federal College of Agriculture, Ishiagu, Ebonyi State, during the 2015/2016 cropping season. The study used a split-plot in a randomised complete block design which aimed at evaluating the effect of different time of planting and manure sources on selected soil chemical properties, maize grain yield and its proximate nutritive values for

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enhanced food security. The soil amendments used and their combinations are poultry droppings (PD), NPK 15:15:15 fertiliser, rice husk dust (RHD), poultry droppings + rice husk dust, NPK + rice husk dust, poultry dropping + NPK + rice husk dust and control. The soil parameters studied include soil pH, organic carbon, total nitrogen and cation exchange capacity. The maize grain yield was determined at harvest and the grain nutrients analysed include moisture content, crude fat, crude protein and ash content percentages. Results showed significant differences among the two planting times and soil amendments in all the soil parameters studied including their interactions. Maize planted in April increased the fresh cobs weight (18.37%) higher than those planted in May (11.19%) as PD amended plots increased the fresh cobs weight (2.71 t/ha) significantly ($P < 0.05$) higher. Maize grain ash percent (1.431%) was improved higher in May than April (1.403%). However, the percentage of moisture contents (MC) and crude fat (CF) (10.46% and 4.237%), respectively, of the maize grain were significantly higher in PD amended plots. Integration of NPK + PD + RHD gave the highest (1.52%) significant ($P < 0.05$) ash percent in the two planting periods. Plots treated with NPK+PD+RHD in May improved the crude protein higher than other treatments. Proper dissemination of this integrated nutrient management approach to the rural farmers could promote sustainable management practices among smallholder farmers, and ultimately sustain and boost maize production.

Keywords: Soil amendments; maize grain yield; nutrient composition; poultry dropping; rice husk dust; proximate analysis.

1. INTRODUCTION

Maize (*Zea mays*) is a globally important cereal primarily used as food, but presently used for animal feed. Apart from providing nutrients for humans and animals, it also serves as a basic raw material for a number of industrial products like starch, oil and protein, alcoholic beverages, food sweeteners and biofuel [1,2]. Despite the industrial uses and nutritional benefits of the crop, its production level in Nigeria, especially in the Southeastern part is still low as to meet with the food security challenges in the area. The low production level could be associated with factors such as environmental factors and poor agronomic practices as manure application. Date of sowing any crop is dictated by many factors including weather, soil condition, management and crop production systems [3]. Temperature is a major environmental agent that determines the rate of plant growth and development. Maize development is primarily driven by temperature, with air temperature being theoretical to enhance maize development from emergence to physiological maturity [4].

Muchow [5] showed that seed growth may be directly influenced by air temperature. Different sowing dates have different environmental conditions such as temperature, solar radiation and rainfall. The most common temperature index used to estimate plant development is growing degree days (GDD), or thermal unit (TU). The accumulation of GDD determines the maturity of plant, yield and yield components. Sur and Sharma [6] reported that the full GDD decreased with the delay in sowing, as the later sown plant experienced lower temperature during the seed filling period. Researchers have shown that time of planting influences the level of soil carbon stock in the tropics [7]. Choosing an appropriate time for planting a particular crop (maize) will help in reducing carbon emission from agricultural lands. Global warming/climate change concerns have led to a surged interest in evaluating or determining effective measures for improving carbon sequestration and reducing carbon accumulation in the atmosphere [8,9]. Storage of soil organic carbon in the agricultural system is a balance between carbon additions from non-harvested portions of the crop [10], organic sources [11], and carbon losses, primarily through organic matter decomposition and release of carbon to the atmosphere [12].

Agriculture is known to be the oldest industry in the world. It's purpose in the growing of crops and rearing of animals, all geared towards the production of food and feed for man and his live-stocks. Over the years, grain yields have depreciated drastically due to the degrading nature of soils, poor fertility management and low input technology to improve the fertility of the soil. Intensive cultivation of introduced high-yielding crop varieties over the years has resulted in depletion of mineral nutrients and hence increased soil acidity. Depletion of soil fertility in tropical regions is very serious due to leaching and erosion of the top soil resulting from intense rainfall [13].

Following limited resources, the growing population and other socio-economic pressures to meet with increasing high demand for food, especially in Nigeria [14], adequate attention should be directed towards massive and cheapest way of food production as to meet the food demand by this increasing population. To achieve this, emphasis should be laid on the easiest means of enriching our soils and analyse the key problems which limit production and expansion of crops such as Maize.

In the humid tropics, use of organic amendments is limited due to the cost of the handling and transportation of large amounts of materials required to meet the crop's nutritional needs [15]. It has been reported that the supply of organic manure is not enough especially in urban areas to substitute the use of chemical fertiliser that has been increasing the acidity levels of tropical soils [16]. However, research has reported that the use of organic amendments, like compost and animal droppings, not only meet the crop nutrient requirements but also maintain long-term soil fertility and productivity improvement [17]. Considering the short comings of sole application of both organic and inorganic fertiliser for soil and crop productivity improvement, it has become necessary to combine different types of these manures. The use of both organic and inorganic amendments has been reported to increase yield, improve and sustain soil characteristics and productivity especially among subsistent farmers in West Africa [18,19]. Complimentary use of organic amendment is a sound fertility management strategy [20] which reduces the farmers over-dependence on the use of inorganic fertilisers [21] which is usually scarce, more expensive, increases soil acidity and causes soil nutrients imbalance.

In Southeastern Nigeria, farmers have continued depending on these inorganic fertilisers which have made prices of many agricultural commodities to skyrocket. The chemical fertilisers used in conventional agriculture contain few minerals, which dissolve quickly in damp soil and give the plants large doses of minerals [22]. Research evidence indicated that the application of organic fertilisers and its integration, therefore, be used to reduce the amount of toxic compounds (such as nitrates) produced by conventional fertilisers in crops, hence, improving the quality of the crop products produced as well as human health [23]. Increased consumer awareness of food safety issues and environmental concerns has contributed to the development of organic farming over the last few years [24,25,26]. Thus, it may be possible to lessen the escalating effects of diseases such as cancer and boost immunity of humans if properly utilised.

Information on food composition data and its chemical components is important in nutritional planning and source of data for epidemiological studies [2,27]. Several been carried the nutritional composition of cereal, legume and tuber [28,29]. However, most producers and consumers of maize grain are not well informed on the effect of different soil amendments and planting seasons on the nutrient composition of maize grain, the knowledge of which is very vital in deciding what kind of soil amendment and planting season is best for maize grain production in Southeastern Nigeria. Determination of proximate and mineral element compositions of maize/maize products will go a long way in providing substantive nutritional information on maize, for an effective guide on dietetics [2].

Therefore, the objective of the study is to evaluate different planting times and manure sources in enhancing soil fertility status, maize grain yield and its nutrients composition in poor resource farmers' field in Southeastern Nigeria.

2. MATERIALS AND METHODS

2.1 Location of the Study

A field experiment was conducted at the teaching farm of the Federal College of Agriculture, Ishiagu, Ebonyi State, during the 2015/2016 cropping season. The study aimed at evaluating the effect of different time of planting and manure sources on selected soil chemical properties, maize grain yield and its proximate nutritive values for enhanced food security. The study area lies within latitude 05°56′N and longitude 07°41′E in the derived savannah zone of Southeastern Nigeria. The area has a mean annual temperature of about 30°C and rainfall of 1350 mm. The major geological material for the area is shale from the Asu River formation. Mean annual rainfall (precipitation) is 1800 mm [30]. The location of the study is within the derived savanna vegetation zone with grassland and tree combinations. The soils are described as Aeric Tropoaquent [31] or Gleyic Cambisol [32]. The soils have moderate soil organic carbon (OC) content on the topsoil, low in pH and low cation exchange capacity (CEC).

2.2 Field Method

The field was cleared, divided into two main plots and each main plot was prepared manually into six seed beds measuring 1.5 m X 2 m which represent the plot size. The treatments were arranged as split-plot in a randomised complete block design (RCBD). The two (2) different time of planting (April and May) constituted the main plots, while the six different sources of manure including the control constituted the sub-plots. The treatments with their rates of application include; poultry dropping at 10t/ha; NPK 15-15-15 at 400 kg/ha; Rice husk dust at 10t/ha; poultry droppings + rice husk at 5t/ha +5t/ha, respectively; NPK + rice husk dust at 200 kg/ha + 5t/ha; poultry dropping + NPK + Rice husk dust at 3.3 t/ha + 133.3 kg/ha + 3.3t/ha, respectively and control replicated three times in each of the main plots.

The treatments were allocated into the plots and incorporated into the soil two weeks before planting except NPK fertiliser treatment which was applied 2 weeks after plant germination.

The test crop used, maize (Zea mays var. Orba super II) was planted using plant spacing of 50cm x 50cm at the rate of three seeds per hole which were later thinned to two seedlings per stand two weeks after planting. Weeding was carried out three weeks and six weeks after planting.

2.3 Data Collection on Plant Parameters

Measurements were taken from the grain yield which was determined using the weighing balance to determine the weight of fresh cob at harvest and shelled grain weight after drying.

2.4 Collection of Soil Samples and Laboratory Analysis

A composite soil sample from different representative field locations was collected from the experimental site, with soil auger at a depth of 0 – 20 cm for initial soil characteristics.

At the harvest, other soil samples were collected from each of the plots to determine the changes that occurred due to treatments application.

The soil samples were air-dried and sieved with 2 mm sieve. Soil fractions less than 2 mm from individual samples were then analysed using the following methods; Particle size distribution of less than 2 mm fine earth fractions was measured by the hydrometer method as described by Gee and Bauder [33]. Soil pH was measured in a 1:2.5 soil: 0.1 M KCl suspensions [34]. The soil OC was determined by the Walkley and Black method described by Nelson and Sommers [35]. Total nitrogen was determined by semi-micro kjeldahl digestion method using sulphuric acid and $CuSO_4$ and Na_2SO_4 catalyst mixture [36]. CEC was determined by the method described by Thomas [37].

2.5 Grain Proximate Analysis

The maize grain nutrients analysed for include: percentage moisture content, percentage crude fat, percentage crude protein and percentage ash content. The determinations of the maize grain nutrients analysis were measured using the methods according to AOAC [38].

2.6 Data Analysis

The data collected were subjected to statistical Analysis of Variance (ANOVA) according to the procedure for split-plot in randomised complete block design and performed using GENSTAT 3 7.2 Edition. The treatment means were separated and compared using fishers Least Significant Difference FLSD at 5% probability level.

3. RESULTS AND DISCUSSION

3.1 Soil Initial Properties and Organic Amendments Nutrient Composition

3.1.1 Soil properties

The soil physical and chemical properties are reported in Table 1. Generally, the soils are sandy loam with 12% clay, 21% g kg^{-1} silt and 67% sand contents.

Soil inventory of the high rainfall region of southeastern Nigeria shows that the major soil unit consists of deep, course textured, well-drained acidic sandy loam, largely derived from coastal plain sand sediments, sandstones and shales. This could affect the growth of crops because of probable low water and nutrient retention capacity and also aid in high leaching of the soil nutrients. Hence, the relatively poor yield of maize on soil not treated with manures was expected [39].

Soil organic carbon concentration was 6.34 g/kg whereas the total soil nitrogen was 1.4 g/kg and the pH measured in water was 5.2 (Table 1). The analysis indicated that the soil was low in CEC with a value of 9.60 cmol/kg.

3.1.2 Organic amendments nutrient composition

Soil amendments comprised of rice-mill wastes or rice husk dust (RHD) collected from a rice-mill industry near the study site. Others included poultry litter droppings (PD) and 15N–15P–15K. Chemical analysis of organic materials indicated that PD had the highest N (2.10%), Ca (14.40%) and phosphorous (2.55%) values; RHD had the highest OC value of 33.75% and C: N ratio of 48.21 (Table 2).

Table 1. Some selected physical-chemical properties of the soil (0-20 cm soil depth)

Soil properties	Value
Clay (%)	12
Silt (%)	21
Sand (%)	67
Textural class	Sandy loam
pH (H_2O)	5.2
Organic carbon (gkg^{-1})	6.34
Total nitrogen (gkg)	1.4
Exchangeable bases ($cmolkg^{-1}$)	
Sodium (Na^+)	0.12
Potassium (K^+)	0.16
Calcium (Ca^{2+})	4.00
Magnesium (Mg^{2+})	2.40
Cation exchange capacity ($cmolkg^{-1}$)	9.60
Base saturation (%)	69.58
Exchangeable acidity ($cmolkg^{-1}$)	1.00
Available phosphorous (mg/kg)	8.39

Table 2. Nutrient compositions (%) in amendments

Property	Amendments	
	Poultry litter droppings	Rice husk dust
Organic carbon	16.52	33.75
Nitrogen	2.10	0.70
Phosphorous	2.55	0.49
Calcium	14.40	0.36
Potassium	0.48	0.11
Magnesium	1.20	0.38
Sodium	0.34	0.22
C: N ratio	7.87	48.21

3.1.3 Effect of different time of planting and different soil amendments on soil pH, nitrogen (gkg^{-1}), soil organic carbon (gkg^{-1}), cation exchange capacity (CEC) ($cmolkg^{-1}$) and Carbon stock (mgm^{-3})

Results presented in Table 3, revealed that the two different times of planting (April and May) showed significant ($P< 0.05$) difference on soil pH, Nitrogen, soil organic carbon and cation exchange capacity (CEC) within the period study.

It was obtained that the soil pH was significantly ($P< 0.05$) improved and was higher in April than May (Table 3). This could be attributed to the variable nature of the environmental factors between these two months of study. It was revealed that environmental factors, especially temperature and rainfall, are the key agents which influence soil pH. This is in agreement with Fatubarin and Olojugba [40] who reported changes in soil pH due to changes in rainfall. The soil pH was observed to have responded positively to the amendments compared with the control plots. The soil pH was best increased (5.85) in the NPK+PD+RHD amended plots and when poultry dropping was combined with rice husk dust (PD+RHD). This could be attributed to the complementary effects of these amendments. Ayeni and Adetunji [39], however, submitted that complementary use of organic and inorganic fertilisers had been a sound soil fertility management strategy for crop production. The adoption of nutrient management practices that integrate organic, chemical and biological inputs into economically and environmentally sound production systems has been reported by Nwite et al. [41] as an essential step towards sustaining high crop yields and preventing land degradation in the region.

However, the result indicated a significant difference in the interaction. The highest interaction was recorded in April on the plots amended with NPK+PD+RHD. This could be attributed to the presence of a required amount of temperature and soil moisture level which led to reduced leaching of the basic cations or the nutrient elements for the enhancement of the soil pH [40].

Total nitrogen concentration was higher in April than May (Table 3). This could be attributed to the increased soil temperature and moisture content in May leading to increased minera-lisation of the nutrient elements due to rapid decomposition of the materials added in the soil. The increased mineralisation of the total nitrogen which is a highly mobile element in soil leads to increased leaching of the element, hence, low availability of the element in the soil. Other studies have reported results in relation to rainfall and temperature effects on the nitrogen content of the soils [42]. This might be the reason why there was low nitrogen content in May. This is in agreement with the findings of Fatubarin and Olojugba, [40] who reported a low nitrogen content of the soil and attributed it to increased soil temperature and moisture.

Total nitrogen differed significantly ($P < 0.05$) among the treatments, with the control and NPK, amended plots showing lower values than other amended plots. Generally, the N contents of the amended soils were very low when compared to its initial value in the soil (Table 1). The low N percent could be related to losses through crop removal since the amended plots performed significantly better in growth and yield than the control plots. This agrees with Ayeni [43] and Nwite et al. [44], who had reported an occurrence of high level of topsoil N volatilisation and denitrification in amendment plots compared to the initial value and losses in surface soil OC and N levels through burning and removal of crop residue. Ayeni, [43] and Nwite et al. [44] submitted that the overall low enhancement of soil total N by amendments compared to the initial value in the soil suggests that a high level of topsoil N volatilisation and denitrification occurred.

Table 3 showed that time of planting significantly affected the soil organic carbon (SOC) concentration with higher SOC been recorded in May. The increased soil organic carbon concentration in May higher than in April is linked to high organic matter decomposition recorded in the month. Results (Table 3) indicated that amendments significantly ($P < 0.05$) improved the soil organic carbon, with poultry dropping (PD) giving the highest significant performance. This was followed by rice husk dust (RHD) and integration of PD and RHD (PD+RHD) treated plots. The higher soil OC in PD, RHD and PD+RHD amended plots than other treated plots including the control were expected because of the increased organic carbon inputs in the materials. To reduce surface OC loss often associated with crop residue removal [46], PD and RHD or their combination should be added to the soil. The low OC in NPK treated plots may be explained by application of a single heavy dose of soluble fertilisers being inefficient in low-activity clay soils that require organic matter to impart appropriate physicochemical and biological properties [45, 30]. In another Ultisol, elsewhere in Southeastern Nigeria, Igwe et al. [30] reported that mineral fertilisers (N–P–K, urea, and ammonium sulfate) reduced soil organic matter level and quality. The results obtained here indicate that the low organic matter status of the typically low-fertility Ultisols needs to be compensated with organic materials and not inorganic fertilisers.

Cation exchange capacity (CEC) was found to be higher in May than April. This was against the expected performance in the CEC as obtained in the soil pH and total nitrogen. This could be as a result of increased level of debris from weed materials and harvested crops which might have increased topsoil humus level, hence, increased CEC.

The highest increase in cation exchange capacity was recorded in PD amended plots. This could be as a result of increased concentration of nutrient elements contained in the PD. Generally, the result indicates that fertilised plots significantly improved the cation exchange capacity higher relative to the control. This is in conformity with the work of Nwite et al. [46], who reported that CEC showed a positive response to manure addition as higher values were found in manured plots compared to non-manured plots. However, the result indicated a significant difference in the interaction of the two factors, with the highest interaction impacts recorded in April on the plots amended with PD.

The effect of different planting times and manure sources on soil carbon stock as presented in Table 4 indicated significant ($P<0.05$) improvement on the carbon stock by the time of planting used. It was obtained that maize plots cultivated in May increased the soil carbon stock higher than those cultivated in April. This could be as a result of change in the weather condition between these two months as May receives more rainfall than April. This result is in line with the submissions of Lal, [47] and Zhang et al. [48] who reported that climate change is an important driver of SOC change. On the other hand, there was no significant ($P<0.05$) improvement in soil carbon stock due to the application of different manures within the period of study. Generally, carbon stock was best increased in plots cultivated in both times of planting by RHD amended plots as it recorded a mean value of 948.52 mg/m^3. More so, the interaction of the planting time and the amendments indicated no significant ($P<0.05$) effect on soil carbon stock.

Table 3. Effect of planting times and soil amendments on selected soil chemical properties

Planting time	Different manure sources							Mean
	CT	NPK	PD	RHD	NPK+RHD	NPK+PD+RHD	PD+RHD	
				Soil pH				
April	5.10	5.60	5.70	5.50	5.20	5.80	5.70	5.61
May	5.50	5.40	5.60	5.70	5.50	5.90	5.70	5.56
Mean	5.30	5.50	5.65	5.60	5.35	5.85	5.70	5.51
LSD 0.05 for Planting times						0.0939		
LSD 0.05 for Manure sources						0.0853		
LSD 0.05 Planting time X Manure sources Interact.						0.1202		
				Total nitrogen (g/kg)				
April	0.84	0.70	1.12	0.98	1.40	2.52	1.12	1.24
May	0.70	0.84	1.12	0.98	0.98	0.98	1.26	0.98
Mean	0.77	0.77	1.12	0.98	1.19	1.75	1.19	1.11
LSD 0.05 for Planting times						0.01626		
LSD 0.05 for Manure sources						0.01192		
LSD 0.05 Planting time X Manure sources Interact.						0.01755		
				Soil organic carbon (g/kg)				
April	6.42	6.92	7.82	8.42	7.56	7.57	8.19	7.56
May	6.61	7.47	8.85	8.19	7.95	8.25	7.98	7.90
Mean	6.52	7.20	8.34	8.31	7.75	7.91	8.09	7.729
LSD 0.05 for Planting times						0.3302		
LSD 0.05 for Manure sources						0.2640		
LSD 0.05 Planting time X Manure sources Interact.						0.3811		
				Cation exchange capacity (cmol/kg)				
April	6.00	9.20	14.00	8.40	11.20	9.60	11.60	10.00
May	11.20	11.60	11.20	10.80	10.80	11.20	9.20	10.86
Mean	8.60	10.40	12.60	9.60	11.00	10.40	10.40	10.43
LSD 0.05 for Planting times						0.03549		
LSD 0.05 for Manure sources						0.03388		
LSD 0.05 Planting time X Manure sources Interact.						0.04740		
				Soil carbon stock (mg/m^3)				
April	696.40	642.73	675.13	884.07	682.23	666.07	711.53	708.31
May	1053.07	967.10	1040.33	1012.97	945.37	1194.83	1044.63	1036.9
Mean	874.74	804.92	857.73	948.52	813.8	930.45	878.08	872.61
LSD 0.05 for Planting times						33.9936277		
LSD 0.05 for Manure sources						NS		
LSD 0.05 Planting time X Manure sources Interact.						NS		

3.2 Effect of Planting Times and Soil Amendments on Maize Grain Yield and Nutrients Compositions

Maize cobs weight (Table 4) differ significantly (P<0.05) among the planting times as higher yield (13.87 ton/ha) was obtained in April. The crop planted during the early part of the year (February-April) passed through lower temperature during early phases and completed their life cycle taking a longer period, hence increased cob yield and grain quality. Poultry dropping (PD) gave higher significant (P < 0.05) cob weight (16.44 ton/ha) and shell grain weight (3.32 ton/ha).

The results (Table 5) indicated that planting time did not significantly (P < 0.05) increased the nutrients composition of the maize grain within the period except on the maize grain ash content. It was obtained that in the maize grain moisture content, though not statistically improved by either of the two planting time, higher moisture level (10.45%) was observed in the maize grain planted in April. However, moisture content of the grain was significantly improved differently among the amendments including the control. It was recorded that plots amended with rice husk dust (RHD) significantly ($P < 0.05$) improved the moisture percent of maize grain higher (10.52%) than others treated plots including the control, while the least moisture percent (10.15%) was obtained in the control plots.

Percentage moisture content (MC), ash, crude fat and crude protein of grains increased more in amended plots than the control (Table 5). %MC was best improved by PD (10.46%). Ash increased higher in May (1.431%) than in April (1.403%). NPK + PD + rice husk dust gave highest (1.52%) significant ($P < 0.05$) ash percentage, as NPK+PD+RHD statistically improved grain crude protein percentage higher (8.608%). This percentage protein was found closely related to those reported on different maize varieties in Nigeria. Notably, Ujabadenyi and Adebolu [49] reported protein of three maize varieties grown in Nigeria within the range of 10.67 –11.25%.

The maize grain crude fibre was significantly (4.24%) increased higher when poultry dropping was applied. The results recorded that integration formular of NPK, PD and RHD; and that of PD plus RHD significantly improved the maize grain crude fibre higher that their sole application within the period. This implies that integrated nutrients management is a better approach in improving maize grain crude fibre.

Maize grain crude protein was statistically enhanced better by the application of sole NPK fertiliser, rice husk dust and the combinations of NPK+PD+RHD in the study. The significant performance of NPK+PD+RHD in line with the sole applications of NPK and RHD means that the integration will reduce the bulkiness of the organic manures to be transported to a distance for application as well reduce the effect total dependence on inorganic fertiliser for the maize grain crude protein improvement.

The results equally indicated that interactions of the planting time and manure application significantly improved the crude protein content of the maize grain with the highest significant improvement recorded in plots treated with NPK+PD+RHD in the month of May.

PD significantly increased crude fat (4.237%) more than the control (3.43%). The percentage fat obtained in this study was consistent with Ikenie et al. [50] and Ujabadenyi and Adebolu, [49] that found grain fat content in the range of 4.17 – 5.0%.

Table 4. Effect of planting times and soil amendments on maize grain yield (t/ha)

Planting time	Different manure sources							Mean
	CT	**NPK**	**PD**	**RHD**	**NPK+RHD**	**NPK+PD+RHD**	**PD+RHD**	
				Maize Fresh Cob Weight (t/ha)				
April	7.55	14.67	19.56	10.11	15.00	15.56	14.67	**13.87**
May	9.33	11.56	13.33	9.22	12.21	10.89	11.78	**11.19**
Mean	**8.44**	**13.11**	**16.44**	**9.66**	**13.61**	**13.22**	**13.22**	**12.53**
LSD 0.05 for Planting times						1.588		
LSD 0.05 for Manure sources						3.259		
LSD 0.05 Planting time X Manure sources Interactions						NS		
				Maize dry shelled grain weight (t/ha)				
April	0.74	1.87	3.93	2.04	2.57	2.20	2.53	2.27
May	1.64	1.97	2.71	1.81	2.43	2.10	2.65	2.19
Mean	1.19	1.92	3.32	1.93	2.50	2.15	2.59	2.23
LSD 0.05 for Planting times						NS		
LSD 0.05 for Manure sources						1.134		
LSD 0.05 Planting time X Manure sources Interactions						NS		

Table 5. Effect of planting times and soil amendments on maize grain moisture content; crude fibre, crude protein contents and ash (%)

Planting time	Different manure sources							Mean
	CT	NPK	PD	RHD	NPK+RHD	NPK+PD+RHD	PD+RHD	
				Maize grain moisture contents (%)				
April	10.19	10.35	10.68	10.57	10.44	10.54	10.39	10.45
May	10.11	10.36	10.24	10.46	10.23	10.36	10.26	10.29
Mean	**10.15**	**10.36**	**10.46**	**10.52**	**10.33**	**10.45**	**10.33**	**10.37**
LSD 0.05 for Planting times						NS		
LSD 0.05 for Manure sources						0.1870		
LSD 0.05 Planting time X Manure sources Interactions						NS		
				Maize grain crude fibre (%)				
April	3.40	3.60	4.20	3.73	3.67	4.09	4.09	3.83
May	3.46	3.61	4.27	3.69	3.60	4.13	4.19	3.85
Mean	**3.43**	**3.60**	**4.24**	**3.71**	**3.63**	**4.11**	**4.14**	**3.84**
LSD 0.05 for Planting times						NS		
LSD 0.05 for Manure sources						0.1874		
LSD 0.05 Planting time X Manure sources Interactions						NS		
				Maize grain crude protein (%)				
April	7.18	8.66	8.34	7.85	8.50	8.50	8.38	8.20
May	7.94	8.69	8.24	7.70	8.57	8.72	8.33	8.31
Mean	**7.56**	**8.67**	**8.28**	**7.78**	**8.54**	**8.61**	**8.36**	**8.26**
LSD 0.05 for Planting times						NS		
LSD 0.05 for Manure sources						0.2132		
LSD 0.05 Planting time X Manure sources Interact.						0.3232		
				Maize grain ash (%)				
April	1.32	1.48	1.33	1.43	1.36	1.52	1.37	1.40
May	1.37	1.51	1.39	1.35	1.48	1.52	1.40	1.43
Mean	**1.34**	**1.50**	**1.36**	**1.39**	**1.42**	**1.52**	**1.39**	**1.42**
LSD 0.05 for Planting times						0.02168		
LSD 0.05 for Manure sources						0.05004		
LSD 0.05 Planting time X Manure sources Interact.						0.06619		

4. CONCLUSIONS

The study concluded that soil organic carbon, cation exchange capacity and soil carbon stock were better improved when planting of maize is done in May as against April, while the soil pH and total nitrogen levels were higher in maize field planted in April. It was also noted that poultry droppings (PD) and the integration of the three amendments performed statistically better than other soil amendments including the control regarding yield and some soil chemical properties. Therefore, adoption of nutrient management practices that integrate organic, inorganic and biological inputs into economically and environmentally sound production systems is an essential step towards sustaining high crop yields, preventing land degradation and health hazards among the consumers in the region.

The moderate moisture content recorded in the current study is important as it enables long storage by minimising fungal contamination and spoilage of the maize/maize products.

Proper dissemination of this integrated nutrient management approach to the rural farmers could promote sustainable management practices among smallholder farmers, and ultimately sustain and boost maize production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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