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Influence of Integrated Nitrogen-Management and Poultry Manure on Growth Analysis and Yield Responses of Maize (*Zea mays*) Cultivated in Relay with Pumpkin and Cowpea

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The ultimate aimed of any agricultural research program is to enhance the productivity of the test crop thereby ensuring food security for the populace. The research was carried out in the research and teaching field of the Institute for Agricultural Research, Samaru, Zaria during the 2019, 2020 and 2022 wet season. The treatments consist of three rates of poultry manure (0, 3 and 6 t ha-1), and two ways of split N application to maize (three split dose and two split dose) replicated four times. Maize and pumpkin were sown same day whereas, cowpea was relayed at 10 Weeks after sowing (WAS) following the harvesting of pumpkin. Result showed that the expression of growth attributes peaked at 10 WAS with the application of poultry manure at 6 t ha-1 producing the tallest

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plant, higher shoot dry matter and leaf area index (LAI). Crop physiological attributes such as Crop Growth Ratio (CGR), Relative Growth Ratio (RGR), and Net Assimilation Ratio (NAR) were significantly influenced by poultry manure with 3 t ha-1 rates of application having higher values. The highest grain yield of maize was obtained with the application of 3 and 6 t ha-1 which gave statistically similar average yield of 5115 and 5146 kg ha-1 respectively. Triple N dose application contributed to 19% increase in yield over double dose application, although not significant. In a general note, among the growth parameters, application of N in three split dosage influences plant height at 8 and 10 WAS; contributing 14.93% increase in plant height over the control, shoot dry matter and LAI. Result indicates that application of 6 t ha-1 of poultry manure and triple split application of 45 kg ha-1 of nitrogen enhances growth attributes of maize such as plant height, shoot dry matter and LAI, but did not translate into higher grain yield of maize. Summarily, for higher grain yield of maize, application of 3 t ha-1 of poultry manure together with 45 kg ha-1 of N fertilizer applied in two (2) split is recommended. Whereas, if the target is for increased vegetative growth, 6 t ha-1 of poultry manure with triple split application of 45 kg ha-1 of nitrogen in Urea form is recommended.

Keywords: Split N application; poultry manure; maize; growth; yield.

1. INTRODUCTION

Maize (*Zea mays* L.) is an important staple food crop in Africa belonging to the Poaceae family. Over 70% of maize in Africa is produced by resource poor small-scale farmers, and the average maize yield in Africa stood at 1.3 t ha^{-1} despite its being a staple compared to 3.0 t ha^{-1} in Europe and America FAO, [1] where it is fed to animals as feed with a current annual production of 12.7 million metric tons in 2022 (FAOSTAT, 2022). Per capita total maize grain consumption is 25.20 kg [2]. Maize cultivation provides food for approximately 900 million people earning less than 2 US dollars per day. Current worldwide consumption stood at 116 million tons with Africa accounting for 30% of global maize consumption, why accounting for just 6.5% of global maize production. In Africa, maize is used as human food, eaten directly as grilled cobs or as various products of maize flour. It is easily stored after drying or milling (Bekeko, 2014). It is an important source of carbohydrate, protein, iron, vitamin B, and minerals and is also use in the production of sugar, corn oil and alcohol [3]. The phytochemicals compounds such as Galanthus nivalis agglutinin (GNA) lectin or GNA-maize presence in maize help prevent chronic diseases such as HIV, bladder problems, nausea, vomiting etc (Shah *et al*. [3] Russel, [4].

Nigeria is one of the important maize producing countries in Tropical Africa (NAERLS, [5] Garba and Namo, [6]. The current production output of maize is relatively low compared to 384 million metric tons produce in USA. Data further showed that by 2050, the world demand for maize will double [7]. In Nigeria, the average yield of maize rally around 2.1 tons/ha [8]. "Intensive high yield agriculture required a balance use of both organic and inorganic fertilizer. This is intended to avoid over reliance on either of the sources whose careless use could result in negative side effects on the environment. This action may provoke public outcry for restriction of its usage. One of the most indicted plant nutrients in that regard is N. Applied N in either organic or inorganic form is subject to several fate, which include; volatilization, leaching, immobilization and denitrification". [9] All this fate according to Dhillon [10] imposes "costs that include loss of productivity and negative environmental impacts; hence, it's important that applied fertilizer particularly the highly mobile ones end up in the plant's tissues".

"Split application of N fertilizer has been considered as a base option to confront these challenges" [11]. "Split application therefore involves dividing the total N requirement of crop, and applying a certain dose at a time; while postponing a portion of the N treatment to a certain time when crop is better able to utilize the nutrient more rapidly and efficiently". [9] In Nigeria, this concept has been adopted by farmers in the northern guinea savanna cereal belt; whereby farmers apply half of the recommended N in conjunction with P and K at planting or two weeks after planting; with the remaining part applied prior to tillering. Hence, this trend may need to be review, particularly in the phase of rapid varietal crop release by both National and International crop research centres. More so, the time lapse of N application and nutrient released which is solely weather dependent particularly temperature and precipitation constitute a major cause for concern. Current knowledge has shown that, no attempts has been made to further deviate from the customary double split dosage of nitrogen application to triple splits dosage; hence the need for this research. Therefore, the major objective of this research is to assess the influence of integrated N-management and poultry manure on growth analysis and yield response of maize (*Zea mays*) cultivated in relay with pumpkin and cowpea in Samaru.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was sited at the Teaching and Research field of the Institute for Agricultural Research Samaru (latitude 11º11´008´N and longitude 7º36´52.1´´E) in the Northern Guinea agro-ecological zone during the 2019, 2020 and 2022 wet seasons. The zone is characterized by a monomodal rainfall pattern. Samaru has a mean annual rainfall of about 1011±161mm concentrated almost entirely in the five months (May/June to September/October) of the cropping season [12]. Samaru soils are classified as Typic Haplustalf according to the USDA soil taxonomy (Ogunwole *et al*., 2001) and Acrisols according to FAO-UNESCO legend [13]. The soil is low in inherent fertility: organic matter, cation exchange capacity and dominated by low activity clays [14].

2.2 Soil Sampling and Analysis

At the beginning of each trial in each year, soil samples were collected from the 0-15 cm layer of the soil across several points in the fields. The collected samples were bulk to form a composite sample from which sub sample was taken for laboratory analysis of physical and chemical properties of the soil prior to treatment administration. Similarly, at the end of the experiment in each year another group of soil samples were collected at the same depth based on treatments to assess soil quality changes as a result of treatments effects on the experimental soils. All collected samples were analyzed at the Agronomy Departmental laboratory of Amadu Bello University, Zaria using standard procedures.

2.3 Treatments

Treatments consist of three levels of poultry manure (0, 3 and 6 t ha^{-1}), two genotypes of cowpea (SAMPEA 11(Determinate) and SAMPEA 14 (indeterminate) and two (2) methods of top dressing of N fertilizer (double split and triple split application). At two weeks after sowing pumpkin and maize, fifty per cent (ie 22.5 kg N ha^{-1}) was applied to all the plots whereas at 4 weeks after sowing maize and pumpkin, the remaining fifty per cent (ie 22.5 kg N ha^{-1}) was applied to plots receiving double split doses nitrogen application whereas, for plot receiving triple splits, the 22.5 kg N ha^{-1} was further splits in two equal doses of 11.25 kg N ha^{-1} and applied at 4 and 6 weeks after sowing maize and pumpkin. Nitrogen was supplied in this trial in form of urea. The sum total of amount of N-fertilizer used for this trial was 50% (or 45 kg N ha^{-1}) of recommended dosage (90 kg N ha^{-1}) for early maturing maize. Pumpkin (*Curcurbita maxima L*) and maize were sown two weeks after land preparation and poultry manure application. The residues of harvested pumpkin were incorporated during earthing-up at 10 WAS, thereafter cowpea was then relayed into the maize. Upon harvest of cowpea, its residues were weighed and incorporated into the soil on the basis of treatments, and soil sampled for physical and chemical analyses.

2.4 Field Layout and Experimental Design

In 2019, the experimental area was ploughed, harrowed twice and ridged 0.75m apart. The experiment was laid out in randomized complete block design (RCBD) with split plot arrangement in four replications. The field was demarcated into four blocks (replication) with each block containing 12 plots. Each gross plots size was 18 m^2 (6 m by 3 m) , and thus representing eight (8) rows while the net plots size was 9 m^2 (3 m x 3 m) representing the four (4) inner rows. One metre (1 m) was allowed between main plots while the distance between one replication and the next was two meter (2 m) apart. Similarly, one plot equivalent was demarcated outside the plot area for the establishment of sole crops of maize (*Zea may*), squash pumpkin (*Curcurbit maxima*) and cowpea (*Vigna unguiculata L*) which received all requisite recommended cultural practices for optimum production of these three crops.

2.5 Varietal Characteristics

***Zea maize* (SAMMAZ 29 variety):** SAMMAZ 29 variety of maize was used. It is a variety developed for Northern Guinea savannah, and transition zones between Sudan and Northern Guinea savannah. It is characterized by early maturity period (75-85 days), highly tolerant to low soil nitrogen and tolerant to striga; the maize variety is also drought and Striga resistant [5]. The variety has an optimum yield of 4.5-5 t ha^{-1}. Two seeds were sown and later thinned to one seed per stand at 2 WAS.

2.6 Cultural Practices

In the three years of the experiment, basal application of 20 kg ha^{-1} each of K as Muriate of Potash (60% K_2O) and P as Single Superphosphate (18% P_2O_5) was done immediately after land preparation to all plots irrespective of treatments. Poultry manure was weighed and applied as per treatment and worked into the soil two (2) weeks prior to sowing pumpkin seeds in each year. Glyphosate at a rate of 4.0 Lha^{-1} at 1.4 kg a.i.ha^{-1} was sprayed two weeks before land preparation to control weed. While supplementary hoe weeding was done at 6 WAS or as the need arises.

2.7 Observation and Measurement

The following observations/measurements were taken at two weeks interval beginning from four weeks after sowing (WAS)

Total leaves area per plant (cm^2): Total leave area was determined for cowpea using leaf area metre model L1-COR 3000.

Crop Growth Rate (CGR) gm^2/week: Crop growth rate (CGR) was determined to assess the rate of dry matter increment per unit area of land per unit time. It was calculated as described by Radford, (1967); thus;

$$CGR = \frac{W_2 - W_1}{T_2 - T_1}\ X\ \frac{1}{G_A}\ (\text{gm}^{-2}\text{wk}^{-1})$$

Where W_2 and W_1 are dry weight in plant at time T_2 and T_1 in weeks respectively and G_A is the ground area.

Relative Growth Rate (RGR) g/g/week: This is the increase in plant materials per unit of plant materials per unit of time. This was estimated as described by Radford [15] thus;

$$RGR = \frac{Loge\ W_2 - Loge\ W_1}{T_2 - T_1}\ (\text{gg}^{-1}\text{wk}^{-1})$$

Where W_2 and W_1 are dry weight in g/plant at time T_2 and T_1 in weeks respectively and $\log_e$ represents natural logarithm.

Leaf Area Index (LAI): LAI is the ratio of leaf surface area per unit of land surface. This was determined as described by Watson (1958) thus;

$$LAI = \frac{A}{LA}$$

Where A=Leaf area and LA =Land area (planting distances of crops)

Net Assimilatory Rate (NAR) gm^{-2}wk^{-1}: This expresses the photosynthetic efficiency of the assimilatory surface. This was estimated as described by Watson [16].

$$NAR = \frac{(W_2 - W_1)}{(T_2 - T_1)} \times \frac{Loge\ A_2 - LogeA_1}{A_2}$$

Where W_1 and W_2 are dry weight of samples in g/plant, A_2 and A_1 are the leaf area and t_2 and t_1 represent the time interval.

Crop yield (Kg ha^{-1}): The harvested cowpea pods of each net plot was dried, threshed; the grains cleared and weighed. From the threshed cobs and pods, the grain weight for the crops were obtained; and later converted to kilogram (kg) per hectare.

$$Crop\ yield\ (kgha-1) = \frac{weight\ per\ net\ plot}{Net\ plot\ size} \times 100$$

2.8 Statistical Analysis

Data generated for the three years were subjected to combined two - way analysis of variance using the General Linear Model (GLM) procedure of SAS; SAS Inst., [17] and significance means were separated at 5% level of probability using standard error of difference (SED).

3. RESULTS

3.1 Experimental Soil Characteristics in 2019, 2020 and 2022

Some physical and chemical properties of the experimental soil site before commencement of the study were determined before the establishment of the trials in 2019, 2020, and 2022 and the results obtained are as shown in Table 1. The results showed that the texture of the soil in the three years was sandy-loam. The soil reaction was slightly acidic in 2019 (6.40), 2020 (5.67) and 2022 (6.23) but did not posed any limitation to maize, pumpkin and cowpea production. Organic carbon and total N were both low in the soil in all the years. However, test values of available P were relatively higher in

2022 (9.99) than 2019 (5.66) and 2020 (8.33). There was gradual increased in organic carbon with relatively higher values reported in 2020 (1.28 %) than 2019 and 2022 (1.21 %). Exchangeable cations (Ca, Mg, and K) were also low with slightly higher values reported in 2022 than 2019 and 2020. Similarly, results of the chemical composition of the poultry manure as shown in Table.2 showed relatively higher proportions of N, P, K and exchangeable bases. Manure pH was relatively high in 2019, than 2020 and 2022 with a corresponding higher concentration of organic carbon.

3.2 Maize Plant Height (cm)

Result of the analysis of variance on the influence of poultry manure rate, methods of N application and cowpea variety on maize plant height in 2019, 2020 and 2022 is presented in Table 3. Result indicates a highly significant ($p<0.001$) effects of poultry manure on maize plant height from 4 - 10 WAS. The tallest plant was produced with the application of 6 t ha^{-1} which was highly significantly ($p<0.001$) different from 3 t ha^{-1} and the control. Also, in all the years, nitrogen application either in double dose or triple splits doses had no significant ($p<0.05$) effects on plant height from 4 to 10 WAS. Similarly, there was significant interaction between poultry manure and method of nitrogen application at 4 and 6 WAS; whereby the application of 6 t ha^{-1} of poultry manure with triple split dose application of nitrogen producing taller plants (Tables 4 and 5).

Table 1. Physical and chemical properties of the soil of the experimental site in 2019, 2020 and 2022

	Level in soil		
Soil Properties	**2019**	2020	2022
Sand (%)	**51.00**	48.00	49.35
Silt (%)	**34.00**	40.00	37.00
Clay (%)	**15.00**	12.00	13.65
Textural class	**Sandy-loam**	Sandy-loam	Sandy-loam
pH 1:2.5 water	**6.40**	5.67	6.23
Organic Carbon (%)	**0.83**	1.28	1.21
Total Nitrogen (%)	**0.06**	0.16	0.10
Available P (mg kg^{-1})	**5.66**	8.33	9.99
Exchangeable Ca^{2+}(Cmol/kg)	**0.60**	2.33	3.86
Exchangeable Mg^{2+} (Cmol/kg)	**0.16**	0.25	0.52
Exchangeable K^{+}(Cmol/kg)	**0.28**	0.16	0.23
Exchangeable acidity (Cmol/kg)	**0.12**	0.20	0.17
ECEC (Cmol/kg)	**1.16**	2.94	4.78

ECEC = Effective Cation Exchange Capacity
Source: Department of Agronomy, Soil analytical laboratory, ABU, Zaria

Table 2. Chemical properties of the poultry manure used in 2019, 2020 and 2022

Manure Properties	**2019**	**2020**	**2022**
pH 1:2.5 water	9.25	9.53	9.39
Organic Carbon (%)	45.63	47.35	46.49
Total Nitrogen (%)	1.71	1.80	1.79
Total P (mg kg^{-1})	3.38	6.03	4.81
Exchangeable Ca^{2+}(Cmol/kg)	7.50	7.43	7.47
Exchangeable Mg^{2+} (Cmol/kg)	12.19	12.16	12.18
Exchangeable K^{+}(Cmol/kg)	1.48	1.44	1.46
Exchangeable acidity (Cmol/kg)	0.16	0.17	0.17
ECEC (Cmol/kg)	21.33	21.20	21.27

Source: Department of Agronomy, Soil analytical laboratory. ABU, Zaria.

Table 3. Combine effect of poultry manure, methods of nitrogen application and varieties on maize plant height, shoot dry matter and LAI at several weeks after sowing in 2019, 2020 and 2022 wet season in Samaru

Season	Plant Height (cm)				Shoot Dry Matter (g/plant)				Lai			
WAS	4	6	8	10	4	6	8	10	4	6	8	10
Poultry manure (t ha^{-1}) (PM)												
0	30.26	104.41	162.93	188.97	11.93	34.76	55.67	84.8	0.96	2.30	2.83	3.34
3	36.83	122.27	180.16	204.8	12.27	53.27	89.93	133.97	1.02	2.49	3.58	4.48
6	41.03	130.47	189.40	214.83	17.89	70.67	114.43	168.46	1.18	3.19	4.47	4.73
SE±	1.503	3.998	4.607	4.377	3.029	5.632	5.887	8.743	0.002	0.003	0.003	0.004
Significance	NS	**	*	*	**	**	*	**	**	**	**	**
Methods of N application (N)												
Double split dose	35.42	119.82	177.33	204.4	13.74	50.47	83.47b	125.20b	1.49	2.97	3.38	3.23
Triple split dose	36.67	118.31	177.7	201.33	12.08	55.37	89.87a	133.07a	1.65	3.20	3.66	3.54
SE±	1.231	3.254	3.810	2.385	2.475	5.804	4.62	7.07	0.002	0.002	0.002	0.001
Significance	NS	NS	NS	NS	NS	NS	*	*	NS	*	*	*
Varieties (V)												
SAMPEA 14	36.39	120.07	177.67	203.33	11.89	52.37	86.63	129.13	1.01	2.56	3.68	4.34
SAMPEA 11	35.69	118.07	177.3	202.4	13.97	53.46	86.73	129.13	1.04	2.49	3.45	4.2
SE±	1.3493333	3.478	3.822	3.623	2.583	6.34	5.833	12.39	0.001	0.002	0.002	0.003
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
Interactions												
PM X N	*	*	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
PM X V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
V X N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
PM X N XV	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*NS=Not Significant, PM=Poultry Manure, N= Methods of N Application. * and ** represent significant difference at 5 and 1 % level of probability. Means having the same letter within a column are statistically similar while those with different letters within the same column are statistically dissimilar*

Table 4. Interaction between poultry manure and methods of nitrogen application on maize plant height at 4 weeks after sowing

	Methods of N application (N)	
	Double split dose	**Triple split dose**
Poultry manure (PM)		
0	43.79d	36.92e
3	40.58c	45.75b
6	44.83b	46.17a
SE (±)	**1.840**	

Means followed by the same letter (s) are statistically similar

Table 5. Interaction between poultry manure and methods of nitrogen application on maize plant height at 6 weeks after sowing

	Methods of N application (N)	
	Double split dose	**Triple Split dose**
Poultry manure (PM)		
0	116.40b	94.90c
3	116.60b	127.80a
6	126.00a	132.30a
SE (±)	**6.470**	

Means followed by the same letter (s) are statistically similar

Table 6. Interaction between poultry manure and methods of nitrogen application on maize shoot dry matter at 8 weeks after sowing

	Methods of N application (N)	
	Double split dose	**Triple split dose**
Poultry manure (PM)		
0	13.10d	14.90d
3	19.20b	17.60c
6	18.70b	21.20a
SE (±)	3.580	

Means followed by the same letter (s) are statistically similar

3.3 Shoot Dry Matter

Maize shoots dry matter as influenced by poultry manure rates, methods of N application and cowpea varieties in 2019, 2020 and 2022 is presented in Table 3. Result indicates that poultry manure significantly ($p<0.001$) influenced maize shoot dry matter from 4 to 10 WAS with higher shoot dry matter reported with the application of 6 t ha^{-1} of poultry manure. Across the various sampling dates, there was a general progressive increased in shoot dry matter with increased rate of poultry manure. Except at 8 and 10 WAS whereby triple split application consistently recorded the highest values at 8 (82 g $plant^{-1}$) and 10 (89.60 g $plant^{-1}$) WAS, methods of N application had no significant effect on shoot dry matter at 4 and 6 WAS. Result further showed significant ($p<0.05$) interaction between poultry manure and methods of N application at 6 WAS whereby the application of 6 t ha^{-1} of poultry manure with triple split dose of N fertilizer reporting significantly ($p<0.05$) higher shoot dry matter (21.90 g $plant^{-1}$) as reflected in Table 6

3.4 Leaf Area Index (LAI)

Leaf Area Index (LAI) of maize as influenced by poultry manure rates, methods of N application and cowpea variety in 2019, 2020 and 2022 is shown in Table 3. Result of the combine analysis of variance indicates that poultry manure highly significantly ($p<0.001$) influence LAI of maize across all the sampling dates with significantly higher values reported with the application of 6 t ha^{-1}. Average values of 4.74, 4.43 and 3.34 were reported at 6, 3 and 0 t ha^{-1} respectively at 10 WAS. Unlike other growth parameters discussed earlier, methods of N application, varieties; as well as their interaction does not significantly affect LAI of maize across the various sampling dates in all the years.

3.5 Crop Growth Rate (CGR) of Maize (g^{-1}/wk^{-1})

Result of analysis of variance of maize CGR as influence by poultry manure, methods of N application and variety in 2019, 2020 and 2022 is presented in Table 7. Poultry manure significantly increased CGR from 4 to 10 WAS in all the years. In 2019, the application of 3 t ha^{-1} recorded the highest (38.50 g^{-1}/wk^{-1}) growth and the least (19 g^{-1}/wk^{-1}) was reported in the control. Method of nitrogen application was only significant in 2019 at 6 – 10 with variable response. At 6-8 WAS the highest (36.70 g^{-1}/wk^{-1}) growth rate was observed with triple split application; whereas, the reverse was the case at 8-10 WAS were double split N dose gave the highest value. In 2020, the maximum crop growth rates were reported at 8 to 10 WAS whereby 6 t ha^{-1} of poultry manure treatment significantly ($p<0.05$) outperformed 3 t ha^{-1} (48.30 g^{-1}/wk^{-1}) and the control (40.10 g^{-1}/wk^{-1}). However, at 4 – 6 WAS, 3 t ha^{-1} (2.57 g^{-1}/wk^{-1}) and the control (1.55 g^{-1}/wk^{-1}) had statistically similar effects on CGR.

3.6 Relative Growth Rates (RGR) ($gg^{-1}wk^{-1}$)

Poultry manure application had significant ($p<0.05$) effects on RGR only at 4-6 WAS in 2020 and 2022. In 2020, the application of 3 (0.27) and 6 (0.25) t ha^{-1} of poultry manure reported the highest values which were at par, but significantly differed from the control (0.22). Furthermore, except at 8-10 WAS in 2019, methods of nitrogen application had no significant effect on RGR of maize in all the years. At 8-10 WAS in 2019, the highest value was obtained with double split N dosage treatment. Similarly, method of nitrogen application, varieties and various main factor interactions showed no significant effects on RGR at different growth phases of maize.

3.7 Net Assimilatory Rate (NAR) ($gg^{-1}wk^{-1}$)

Net assimilatory rate (NAR) of maize as influence by poultry manure, methods of N application and cowpea varieties in 2019, 2020 and 2022 wet season is presented in Table 8. Result of the analysis of variance in 2019 as presented in Table.8 indicates that except at 4-6 WAS, poultry manure treatment had no significant effects on NAR of maize. At 4-6 WAS, the highest (2.152 $gg^{-1}wk^{-1}$) NAR was reported in 6 t ha^{-1} poultry manure rates, while the least (0.590 $gg^{-1}wk^{-1}$) was reported in the control. Generally, results obtained at 4-6 WAS in 2019 indicates a progressive increase in NAR with increased rate of poultry manure. Methods of nitrogen application and variety had no significant effects on NAR across all the sampling dates. Result further indicates significant interaction between poultry manure and methods of N application at 4-6 WAS; whereby the application 6 t ha^{-1} of poultry manure with triple split N application gave the best result on NAR with an average value of 2873 $gg^{-1}wk^{-1}$ (Table 8).

Result of NAR in 2020 is presented in Table 8. Result indicates that poultry manure treatment only significantly affects NAR at 4 – 6 WAS whereby the increase in the rates of poultry manure from 0 - 6 t ha^{-1} gave significantly higher (0.748 $gg^{-1}wk^{-1}$) values followed by 3 t ha^{-1} (0.413 $gg^{-1}wk^{-1}$) and the least (0.145 $gg^{-1}wk^{-1}$) reported in the control. Similarly, main factors interaction was not significant in 2020.

In 2022, NAR of maize was significantly affected by poultry manure in all the growth phases of the crop with significantly higher values reported with 6 t ha^{-1} applications relative to the control. The maximum NAR was reported at 6 - 8 WAS followed by steep dropped at 8-10 WAS. Nitrogen application in triple split doses gave significantly ($p<0.05$) higher values (2.399 $gg^{-1}wk^{-1}$) of NAR compared with double doses. However, across all the growth phases, there was no significant ($P<0.05$) interaction between the main factors. Generally, in all the years, the maximum NAR was reported at 4 - 6 WAS with an abrupt declined at 8 – 10 WAS.

3.8 Maize Grain Yield (kg ha^{-1})

Result of the influence of poultry manure, methods of N application and cowpea varieties on maize grain yield in 2019, 2020, and 2022 is presented in Table 9. Result indicates that poultry manure significantly ($p<0.05$) increased maize grain yield in 2019, 2020 and 2022 cropping season. Significantly higher maize grain yield was reported with 6 t ha^{-1} rate of application in all the years and combined. In 2020, result indicates that both 6 and 3 t ha^{-1} produced statistically similar effects on maize grain yield.

Table 7. Combined effects of poultry manure, methods of nitrogen application and varieties on Crop growth rate, Relative growth rates (RGR) (gg-1wk-1), NAR (gg-1wk-1) at several weeks after sowing during 2019, 2020 and 2022 wet seasons in Samaru

Season	**CGR**			**RGR**			**NAR**		
WAS	**4-6**	**6-8**	**8-10**	**4-6**	6-8	**8-10**	**4-6**	**6-8**	**8-10**
Poultry manure (t ha^{-1}) (PM)									
0	19.85c	28.10c	55.37c	0.18b	0.22	0.08a	0.40b	0.26c	0.08
3	38.06b	50.03b	84.60b	0.20a	0.23	0.07b	1.08a	0.70b	0.16
6	51.27a	62.03a	100.83a	0.21a	0.22	0.07b	1.93a	1.08a	0.17
SE±	7.485	9.27	12.39	0.028	0.024	0.013	0.615	0.214	0.063
Significance	*	**	*	*	NS	*	*	**	NS
Methods of N application (N)									
Double split	15.88	49.57	33.13	0.18	0.22	0.10	0.90	0.6528	0.16
Triple split	40.24	43.83	44.13	0.21	0.22	0.09	1.37	0.7078	0.12
SE±	6.110	7.980	11.191	0.022	0.019	0.009	0.3863	0.175	0.052
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS
Varieties (V)									
SAMPEA 14	36.29	70.95	73.1	0.19	0.23	0.07	1.3956	0.77	0.16
SAMPEA 11	35.98	67.85	77.27	0.19	0.22	0.07	0.87	0.58	0.12
SE±	7.190	9.203	10.573	0.023	0.019	0.010	0.425	0.167	0.052
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions									
PM X N	NS	NS	NS	NS	NS	NS	NS	NS	NS
PM X V	NS	NS	NS	NS	NS	NS	NS	NS	NS
V X N	NS	NS	NS	NS	NS	NS	NS	NS	NS
PM X N XV	NS	NS	NS	NS	NS	NS	NS	NS	NS

*S= Not Significant, PM=Poultry Manure, N= Methods of N application. * and ** represent significant difference at 5 and 1 % level of probability. Means having the same letter within a column are statistically similar while those with different letters within the same column are statistically dissimilar*

Table 8. Interaction between poultry manure and methods of nitrogen application on maize NAR at 4-6 weeks after sowing in 2019 wet season

	Methods of N application (N)	
	double split dose	Triple split dose
Poultry manure (PM)		
0	0.906c	0.273d
3	1.133b	0.650c
6	1.143b	2.273a
SE (±)	**0.416**	

Means followed by the same letter (s) are statistically similar

Table 9. Effects of poultry manure, methods of nitrogen application and varieties on maize grain yield at harvest in 2019, 2020 and 2022

	Grain yield (kg ha-1)			
Treatment	**2019**	**2020**	**2022**	**Combined**
Poultry manure (t ha^{-1}) (P)				
0	4041c	3703c	2125c	3873b
3	4617b	5313b	3368b	5115a
6	4974a	5617a	4000a	5146a
SE±	251.6	539.4	324.2	395.5
Significance	*	**	*	*
Methods of N application (N)				
Double split dose	4736	5017	3306	4877
Triple split dose	4633	4739	3023	4686
SE±	217.7	440.4	264.7	329.0
Significance	NS	NS	NS	NS
Varieties (V)				
SAMPEA 14	4385b	4697	293.50	4541
SAMPEA 11	4983a	5058	3394	5021
SE±	205.5	463.4	257.5	334.5
Significance	*	NS	NS	NS
Interactions				
PM X N	NS	NS	NS	NS
PM X V	NS	NS	NS	NS
V X N	NS	NS	NS	NS
PM X N X V	NS	NS	NS	NS

*PM=Poultry Manure, N= Methods of N Application. * and ** represent significant difference at 5 and 1 % level of probability. Means having the same letter within columns are statistically similar while those with different letters within the same columns are statistically dissimilar, NS=Not Significant*

Result further showed that method of N application does not significantly influenced maize grain yield in all the years and combined. Varietal effect was only significant in 2019 with SAMPEA 11 statistically outperforming SAMPEA 14. No significant interaction was reported among main factors in 2019, 2020 and 2022.

4. DISCUSSION

Result shows that the selected growth and yield attributes of maize were significantly ($P<0.05$) improved with increased rate of poultry manure, with consistently higher yield reported at 6 t ha^{-1}. This could be due to the balance proportion of macro (particularly N, P and K) nutrient content of the poultry manure added to the soil. The release of nitrogen from the poultry manure must have stimulated high vegetative growth which at later stage had resulted in high assimilate transfer to thereby accounting for higher yield. The high nutrient content of the poultry manure is a function of the high-quality protein contains in the poultry feed ingested by the bird. The potential of poultry manure as a plant nutrient source have been recognized by a number of researchers who have reported consistently higher crop performance from its usage. Nutrient held in poultry manure in contrast to cow dung and goat kraal are readily made available for crop uptake within a giving production cycle. Dekissa *et al*. [18] reported that poultry manure is an excellent organic fertilizer that contains high N, P, K, and other essential nutrients which in contrast to inorganic fertilizer contribute significant amount of organic matter to the soil thereby improving it physical, chemical and biological properties. Thus, in this study, the lower bulk density and higher organic carbon at higher rate of poultry manure in addition to increase canopy cover imposed by maize/pumpkin and cowpea intercropping help in conserving soil moisture; thereby providing a suitable growth medium for easy mineralization, release, absorption and uptake of applied nutrient by the root of maize. This corroborates the finding of Lal and Stewart [19] who reported favourable effects of organic manure on soil organic carbon and water retention. Other factors contributing to the yield advantage particularly above the optimum reported for the zone as observed in this finding could be a better rainfall amount and distribution, particularly at the most critical growth phases of the crop. The general field improvement of the soil properties as evidenced in the relatively high organic carbon, total nitrogen and available P values reported at the end of the experiment must have contributed to the enhance growth and yield of the maize. Similarly, the combine application of poultry manure and mineral fertilizer must have improved soil fertility throughout the growing season, especially at the later period of growth, which ultimately enhanced root growth, and allowed more nutrient uptake for higher photosynthetic activity, resulting in maximum crop growth and biomass production. This agree with Kunlola and Adelusi [20] who observed that plants grown at optimum nutrient level generally produce larger leaves and greater allocation of photosynthetic protein (assimilate partition) than those at low nutrient availability.

Result also showed a significant reduction in growth indices such as CGR, RGR, and NAR of maize, from 8 to 10 WAS. This reduction could be as a result of leaf senescence at 10 WAS and damage of older leaves by insect (Army worms) attack which tend to reduce assimilatory surfaces for photosynthetic activities. This finding corroborates those reported by Biswass [21] on potato/wheat mixture in Bangladesh whereby LAI and CGR was found to increased linearly with increased nutrient level up to 60 days after sowing followed by a reduction at later stage of the crop growth. Whereas, the high nitrogen content of the applied poultry manure in addition to the supplementary inorganic nitrogen application may be responsible for the increased in maize physiological attributes such as CGR, LAI, NAR etc at higher rates of poultry manure treatment. This agreed with Bharadwai, [22]who observed that nitrogen help facilitates the rates of conversion of carbohydrates to protein which in turn is important in the structure of the protoplasm by increasing the size which is manifested morphologically in increased in LAI, NAR and CGR.

5. CONCLUSION

Result indicates that application of 6 t ha^{-1} of poultry manure and triple split application of 45 kg ha^{-1} of nitrogen enhances growth attributes of maize such as plant height, shoot dry matter and LAI, but did not translate into higher grain yield of maize. Summarily, for higher grain yield of maize, application of 3 t ha^{-1} of poultry manure together with 45 kg ha^{-1} of N fertilizer applied in two (2) split is recommended. Whereas, if the target is for increased vegetative growth, 6 t ha^{-1} of poultry manure with triple split application of 45 kg ha^{-1} of nitrogen in Urea form is recommended.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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