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## **Effect of Integrated Chicken Manure and Inorganic Fertilizers on Growth and Yield of Hybrid Maize (*Zea Mays. L.*) in Malawi**

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### **Abstract**

Fertilizer application is necessary for optimal maize (*Zea mays. L.*) yields in Malawi due to declining soil fertility. Use of inorganic fertilizer is expensive for smallholder farmers. The study was conducted to evaluate effect of integrated organic and inorganic fertilizer utilization on nitrogen uptake, growth and yield of hybrid maize in Malawi. Field experiments were carried out in Lilongwe and Zomba Districts during the 2016/17 growing season. A split plot layout in a randomized complete block design with 3 replicates was used. Maize varieties SC403 and SC627 were the main plots. The sub plots were six fertilizer treatments: (T1); 4 t ha<sup>-1</sup> chicken manure (CM), (T2); CM and 22.5 kg N ha<sup>-1</sup>, (T3); CM and 45 kg N ha<sup>-1</sup>, (T4); CM and 67.5 kg N ha<sup>-1</sup>, (T5); CM and 90 kg N ha<sup>-1</sup> and (T6); a no fertilizer input control. Urea fertilizer was the source of mineral N. Data on maize height, stem girth, biomass and grain yield was collected and subjected to analysis of variance (ANOVA) using SAS programme. Mean separation was done using Fishers LSD, at 95% probability level. The study indicated that organic manure and inorganic fertilizer integration significantly ( $P<0.05$ ) affected maize growth and yield. The maximum maize height and girth were attained by use of CM and 22.5 kg N (T2) which is quarter of recommended fertilizer rate.

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Increasing fertilizer rate did not significantly affect maize growth. Fertilizer treatment combination of 4 t ha<sup>-1</sup> chicken manure and 90 kg N ha<sup>-1</sup> ensured the highest grain yield value of 6.3 t ha<sup>-1</sup> but the use of 4 t ha<sup>-1</sup>CM and 45 kg N ha<sup>-1</sup> on SC627 maize variety produced a mean yield of 4.6 t ha<sup>-1</sup> which is higher than the average yield of 2.5-3.0 t ha<sup>-1</sup> attained by smallholder farmers, besides judicious use of inorganic fertilizer for sustainable maize production. Thus, the promising combination is fertilizer treatment 'T3' (4 t ha<sup>-1</sup> CM and 45 kg N ha<sup>-1</sup>) and SC627 maize variety in boosting maize production for food security affordably by smallholder farmers in Malawi.

**Key words:** Maize (*Zea mays*. L); Chicken manure, Yield.

## 1. Introduction

Soil fertility decline is increasingly being viewed as a critical problem affecting agricultural productivity in sub-Saharan Africa (SSA) [1]. The decline in soil fertility is as a result of a combination of high soil erosion rates, leaching, removal of crop residues and continuous cultivation of land without adequate fertilization or fallowing [2]. The use of inorganic fertilizer has been proven to be effective in boosting maize crop yield as the nutrients are readily available for plant absorption and utilization one applied in the soil [3].

Maize (*Zea mays*. L) is the main staple food for the Malawi's population. It is mainly produced by smallholder farmers who own an average 0.23 ha of arable land. The total arable land is 40.3% of the total land, and farmers are able to produce an average of 2100 kg ha<sup>-1</sup> of maize [4]. In Malawi, the rate of soil nutrient depletion is at an average of 100 kg NPK/ha/year [5]. The inorganic fertilizer rate used by small holders is very low. The major challenge for smallholder farmers to sustainably produce maize is the access to fertilizer. This has resulted into low maize yields.

The use of inorganic fertilizer has increased from 120 Kg ha<sup>-1</sup> to 140Kg ha<sup>-1</sup> worldwide. However, intensive utilization on chemical fertilizer has great impacts on the environment, as it aggravates soil degradation [6].

Organic fertilizers are carbon-based compounds added derived from animal matter, human excreta or plant based materials. The application of organic matter needs to be maintained for sustainable agriculture [7]. The use of organic matter in soil fertility improvement is essential because despite supplying essential nutrient to the plants, it also improves soil water availability, soil temperature, cation exchange capacity and soil pH buffering capacity [8]. The capacity of organic manure to store nutrient elements in the soil and slowly releasing them, enables reduction in nutrient loss through denitrification and leaching hence promoting nutrient uptake [6]. The major challenge faced with utilization of organic matter is the low nutrient concentration in comparison with the inorganic fertilizer and the variability in their nutrient contents [9]. The application of manure only does not improve yield to the required level [10].

Integrated approach is a systematic nutrient elements application method to plants involving the use of both organic and inorganic sources to meet the plant's nutrient requirements. It involves determining the nutrient levels in particular manure that is used in crop production. Nutrient element supplementation of the organic source to meet the crop nutrient requirement is done by addition of inorganic fertilizer. This is done to ensure

maximum crop yield at a relatively lower cost as compared to use of inorganic fertilizer only.

The study was aimed at studying the effectiveness of integrated chicken manure and inorganic fertilizer on nutrient uptake, growth and yield of hybrid maize (*Zea mays*. L.) in Malawi.

## 2. Materials and Methods

### 2.1 Site description

The study was conducted at Chitedze and Makoka research stations in Malawi, during 2016/2017 season. Chitedze (1146 m asl) is located at a longitude of 13°85` E and latitude 33°38` S. The site has an average temperature of 20.3°C and receives an averaged unimodal rainfall amount of 860 mm per year (Appendix 1). The soils were sandy Clay Loam with a pH range of 5.9-6.2 (Appendix 2). Makoka Experimental Station is located in the southern part of Malawi at 15° 32` south and 35° 11` East with an altitude of 949 m asl. The average temperature of the area is 21.1°C and received an average rainfall of 1282 mm annually (Appendix 1). The site was characterized with Sandy loam (SL) soil with a soil pH range of 4.5-7.0 with generally low fertility (Appendix 2).

### 2.2 Experimental layout and treatments

A split plot layout in a randomized complete block design with three replicates was used in both sites. Two maize varieties (SC403 and SC627) were the main plots and the fertilizer treatments were the sub plots (Table 1).

**Table 1:** Fertilizer treatment combinations

Treatment	Fertilizer treatment combination
T1	Chicken manure (CM) only (4 t ha <sup>-1</sup> )
T2	Chicken manure (4 t ha <sup>-1</sup> )+ 22.5 Kg N ha <sup>-1</sup>
T3	Chicken manure (4 t ha <sup>-1</sup> )+ 45 Kg N ha <sup>-1</sup>
T4	Chicken manure (4 t ha <sup>-1</sup> )+ 67.5 Kg N ha <sup>-1</sup>
T5	Chicken manure (4 t ha <sup>-1</sup> )+ 90 Kg N ha <sup>-1</sup>
T6 (Control)	No fertilizer input

### 2.3 Agronomic practices

The land was cleared and tilled using a tractor to a depth of 45cm, giving a moderately fine tilt. Planting ridges were mechanically constructed, 0.75m apart, along the slope. Maize seeds were planted 0.25m apart, on top of the ridges, with one seed per planting station to give a plant population of 53333 per hectare.

Chicken manure was cured before use and was placed under shade for three weeks. This was aimed at mineralizing the nutrients present and stabilizing the manure to avoid scorching the germinating plants. It was thereafter applied at constant rate of 4 t ha<sup>-1</sup> in designated plots two weeks before planting using a calibrated container. Urea (46%N) and triple super phosphate (21% P) fertilizers were used as inorganic fertilizers. Urea fertilizer, was applied in two splits, 7 days after planting and as a top dressing at 28 days after planting, at different rates (Table 1). Triple superphosphate was applied as basal fertilizer at a rate of 40 kg ha<sup>-1</sup>P.

Weeding was done manually using a hoe prior to basal and top fertilizer dressing.

#### ***2.4 Analysis of soil and manure samples***

Soil samples collected from the two sites were collected using a transverse sampling method. An Edelman soil auger was used to collect 12 soil samples of top and sub soil in a single location at a depth of 15 and 45 cm respectively. The 12 samples were used to formulate composite samples of top and sub soils for laboratory characterization of physical and chemical properties (Appendix 2). The Chicken manure characterization for nutrient content, a sample of cured chicken manure weighing 500g was randomly collected from the bulk of the cured manure.

The samples were prepared for laboratory chemical analysis through: air drying; grinding and sieving then labelled. Soil organic carbon was determined using calorimetric method as described by Okalebo [11]. Exchangeable bases (P, Ca, Mg and K) from the soil samples were determined by Mehlich 3 method (Appendix 2). The total nitrogen from both samples was determined by Kjeldahl method as described by Bremer [12]. The soil pH was determined using the glass electrode pH meter as described by Okalebo [11].

#### ***2.5 Growth and yield parameters measured***

##### ***2.5.1 Stem girth***

The stem girth data was collected on fortnightly basis, starting at 4 weeks after planting. The data was collected by measuring the stem thickness at the base of the maize stalk stem using a measuring tape. Three plant sampled plants in each sub-plot were used to obtain the average stem girth per sub-plot [13].

##### ***2.5.2 Plant height***

Average maize height was determined using a measuring ruler from the three tagged maize plants per sub-plot. The plant height was considered from the stem above ground to the end of the last node in meters [13], every fortnight from 4 weeks after planting.

##### ***2.5.3 Plant Biomass***

The data on biomass was collected at physiological maturity state when the plants had dried. Three sampled maize stocks from each harvestable plot (4 middle plot rows) were cut just at the ground level. The aboveground

biomass excluding the cobs was weighed and average weight recorded.

#### 2.5.4 Maize grain yield

Harvesting was done after the maize had dried upon attaining physiological maturity. Each sub plot was harvested separately, from two middle rows, and packed in separate labelled sack bags. The maize grain was further air dried until the moisture level ranged between 13- 14%, for yield determination. The maize gains were air dried and a moisture content meter was used to know measure the moisture content level. Grain yield and cob weight from each net plot were measured at standard average moisture content of 13-14%. The grain yield was determined by multiplying average plant yield with the total number of plants per hectare (53,333 plants).

#### 2.6 Data analysis

The data collected was subjected to analysis of variance using SAS program, version 9.3. The means were separated using Fisher's protected least significance difference performed at 95% significance level (SAS Institute, 2011)

### 3. Results and Discussion

#### 3.1 Maize Girth

The girth of the hybrid maize was significantly ( $P < 0.05$ ) influenced by the combined effects of nitrogen level, location and maize variety; nitrogen level and location besides nitrogen level and maize variety treatments interactions (Table 2). Time interactions across the season did not statistically influence ( $P < 0.05$ ) the mean girth of the hybrid maize.

**Table 2:** Three-way interaction effect of nitrogen level, location and maize variety on maize girth in Malawi, 2016/17 growing season (Mean $\pm$ SE)

Treatment	Makoka Site		Chitedze site	
	Variety		Variety	
	SC403	SC627	SC403	SC627
T1	5.75 $\pm$ 0.28	7.82 $\pm$ 0.21	5.77 $\pm$ 0.30	6.29 $\pm$ 0.36
T2	7.38 $\pm$ 0.25	7.72 $\pm$ 0.32	7.15 $\pm$ 0.19	6.97 $\pm$ 0.29
T3	8.22 $\pm$ 0.33	7.67 $\pm$ 0.16	6.78 $\pm$ 0.24	6.97 $\pm$ 0.39
T4	7.96 $\pm$ 0.27	7.74 $\pm$ 0.32	6.71 $\pm$ 0.24	7.55 $\pm$ 0.40
T5	7.86 $\pm$ 0.27	7.78 $\pm$ 0.33	6.94 $\pm$ 0.23	7.03 $\pm$ 0.38
T6	5.44 $\pm$ 0.44	6.31 $\pm$ 0.50	6.68 $\pm$ 0.32	7.23 $\pm$ 0.42
CV				10.98
R <sup>2</sup>				0.81

T<sub>1</sub>= 4 T ha<sup>-1</sup> chicken manure (CM), T<sub>2</sub>= CM + 22.5kg mineral N + 21% P, T<sub>3</sub>= CM + 45 kg mineral N + 21% P, T<sub>4</sub>= CM + 67.5 kg mineral N + 21% P, T<sub>5</sub>= CM + 90 kg mineral N + 21% P, T<sub>6</sub>= No fertilizer input.

In the three way interaction effect (nitrogen level\*variety\*location) on girth of SC403 hybrid maize grown at Makoka site and subjected to T3 nitrogen level had the highest mean value 8.22 cm (Table 2). Maize variety SC403 subjected to nitrogen level T6 had the least girth with a mean value of 5.44 cm. Makoka site generally had a higher mean girth as compared to maize planted at Chitedze site. Maize variety SC627 generally had thicker maize stalks as compared to SC403 maize variety in all the sites.

There were no significant differences (P<0.05) in mean girth of maize plants subjected to fertilizer treatments level: T2; T3; T4 and T5. Fertilizer treatment T6 which had the lowest mean effect of 6 cm girth. The optimum girth was obtained at low nitrogen levels, and it implies that less nitrogen is required to have maize plants with a normal girth of 7.0-7.5cm. This can be attributed to the developmental stages of the plant. Stem development mostly happens before reproduction stage peaks up hence more nutrients are not stored in grains but rather used for the plant statue development. The highest mean girth of 7.26 cm was obtained in variety SC627, which implies that it capable of storing a lot of photosynthates for use during senescence as opposed to variety SC403 which had a lower mean girth hence having a lower sink for photosynthates storage [14]. Makoka site had the highest mean girth as compared to Chitedze site and this is attributed to the optimal environmental factors such as rainfall and temperature in Makoka site as compared to Chitedze (Appendix 1).

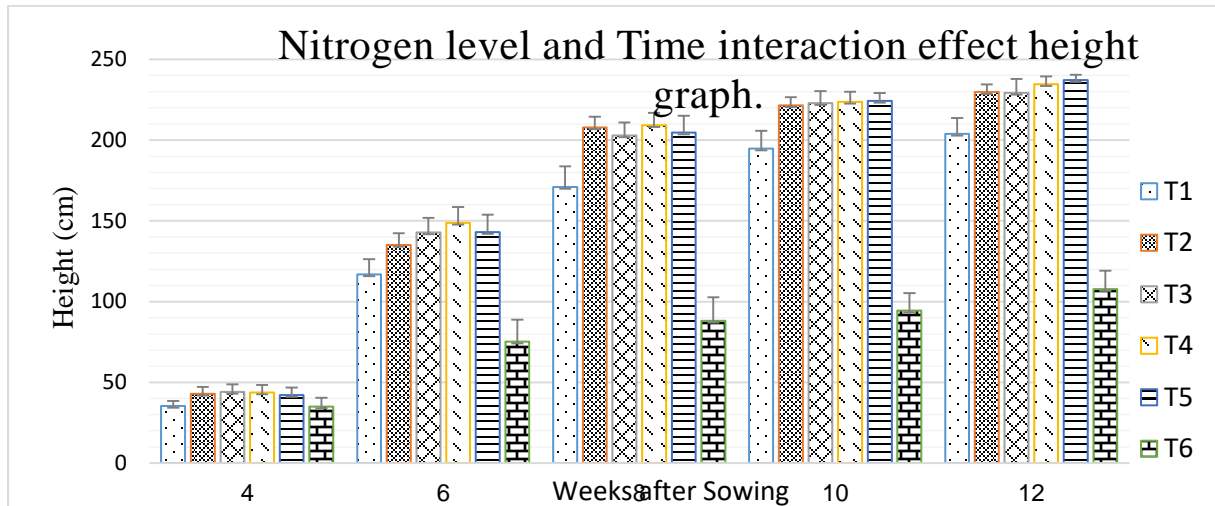
### 3.2 Maize height

The plant's height increased with time from the date of planting to the 12 week of growth which was the final week of data collection on growth traits ( Figure. 1). Between planting date and the fourth week plants experienced a steady increase in height as compared to the other intervals (Figure 1).

**Table 3:** Three-way interaction effect of nitrogen level, location and maize variety on maize height in Malawi during 2016/17 growing season (Mean±SE)

Treatment	Makoka Site		Chitedze site	
	Variety		Variety	
	SC403	SC627	SC403	SC627
T1	121.29 ± 16.73	175.79 ± 21.29	149.68 ± 15.97	140.29 ± 17.44
T2	164.37 ± 19.75	179.87 ± 22.09	144.54 ± 16.38	170.68 ± 18.77
T3	167.73 ± 20.85	156.99 ± 20.87	170.31 ± 16.62	158.21 ± 19.51
T4	174.08 ± 20.36	177.27 ± 22.17	173.97 ± 16.62	152.35 ± 18.98
T5	175.68 ± 20.66	176.10 ± 21.42	173.52 ± 16.84	145.52 ± 20.54
T6	109.90 ± 17.32	126.28 ± 19.84	123.25 ± 15.87	130.93 ± 19.34
CV				12.44
R <sup>2</sup>				0.95

T<sub>1</sub>= 4 T ha<sup>-1</sup> chicken manure (CM), T<sub>2</sub>= CM + 22.5kg mineral N + 21% P, T<sub>3</sub>= CM + 45 kg mineral N + 21% P, T<sub>4</sub>= CM + 67.5 kg mineral N + 21% P, T<sub>5</sub>= CM + 90 kg mineral N + 21% P, T<sub>6</sub>= No fertilizer input.



**Figure 1:** The progression of maize height as affected by the interaction of nitrogen level and variety in Malawi during 2016/17 growing season.

T<sub>1</sub>= 4 T ha<sup>-1</sup> chicken manure (CM), T<sub>2</sub>= CM 4 T ha<sup>-1</sup> + 22.5 kg mineral N + 21% P, T<sub>3</sub>= CM4t ha<sup>-1</sup> + 45 kg mineral N + 21% P, T<sub>4</sub>= CM 4 t ha<sup>-1</sup> + 67.5 kg mineral N + 21% P, T<sub>5</sub>= CM 4t ha<sup>-1</sup> + 90 kg mineral N + 21% P, T<sub>6</sub> = No fertilizer input.

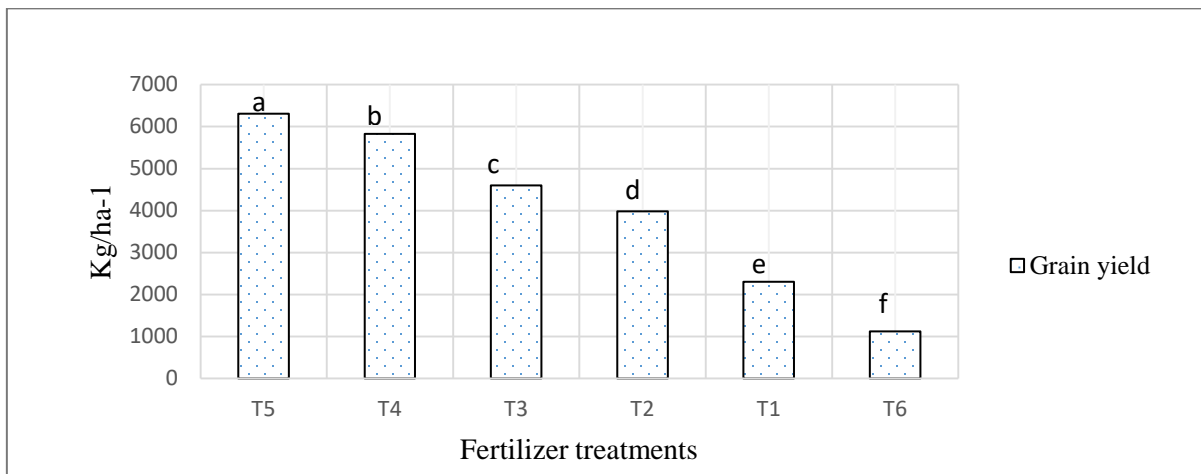
Fertilizer treatment T<sub>6</sub> which had no form of fertilizer applied to the maize varieties had the least growth rate during the 12 weeks when data was collected. This is attributed to the lack of supplementary nitrogen fertilizer application, therefore the plants probably relied only on the nitrogen present in the soil [15]. Maize plants subjected to fertilizer treatment T<sub>6</sub> (No fertilizer input) had a stunted growth in height due to lack of nutrients such as nitrogen which is essential for growth as it is a component of cell nucleus and production of hormones such as Auxins and Gibberellins which are essential for cell growth and elongation [16]. Application of chicken manure (T<sub>1</sub>) ensured a mean height that was statistically different ( $P < 0.05$ ) from the no fertilizer treatment (T<sub>6</sub>). Fertilizer treatment T<sub>2</sub> (CM + 22.5kg mineral N + 21%P) ensured mean heights at all stages of maize development that were not significantly different to the other treatments where nitrogen supply was high. The growth in height for fertilizer treatment T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub> with time in was not statistically different ( $P < 0.05$ ) at all stages of development. This implies that for optimum height, fertilizer treatment T<sub>2</sub> is the best economically as it produced the same results as fertilizer treatment T<sub>5</sub>. The extra N supplied by fertilizer treatments T<sub>3</sub> to T<sub>5</sub> was probably used for grain filling which ensured maize grain yield as illustrated in figure 6. During vegetative growth, most nutrients are used for cell growth as compared to other plant functions such as reproduction phase which includes grain filling. Besides this, in later stages of plant development photosynthesis rate declines due to decline in chlorophyll activity which signals the plant to utilize most of its energy in grain development for generation continuation and survival [15]. Fertilizer treatment T<sub>5</sub> had the highest mean height effect of



188.34cm on the maize and was significantly different ( $P < 0.05$ ) from all other fertilizer treatments with T6 treatment having the lowest mean height of 37.57cm. For maximum growth in height T5 fertilizer was the best, though it's not the best attribute of maize survival as the maize is prone to lodging due to the effect of wind [17]. Maize variety SC627 had a higher mean height of 114.22cm due to its genetic characteristics of longer pre-anthesis period and significantly different ( $P < 0.05$ ) as compared to SC403 which had 112.61cm due to its shorter pre-anthesis period. The maize varieties at Makoka had the higher mean height of 44.2 cm and 43.60 cm for maize varieties SC627 and SC403 respectively in the fourth week after planting as compared to maize varieties at Chitedze site which had a mean height 39.99 cm and 35.98 cm for maize variety SC627 and SC403 respectively. This was due to the favorable conditions for nutrients uptake and maize growth. The considerably even distribution of rainfall at Makoka site probably reduced the denitrification rate in the soil due to the cooling effect on the soil hence much nitrogen that was applied being taken up by the maize [18]. At Chitedze site, the reduced height and girth is attributed to the less water supply for regular soil nutrient absorption and uptake, hence imparting on cell division and elongation of the maize plants [18].

### 3.3 Maize yield attributes

The yield of maize grain is a product of photosynthetic processes which happens in the maize leaves. The photosynthetic rate depends on the availability of resources such as plant nutrients, moisture, heat and the plant itself. The lower the resources the lesser capacity the plant has to produce its optimal grain yield. Biomass included all the above ground mass (stem, leaves and the tassels). Maize plant growth is determined by both genetic and environmental factors [19].



**Figure 2:** Effect of nitrogen level on hybrid Maize grain yield in Malawi during 2016/17 growing season

T<sub>1</sub>= 4 T ha<sup>-1</sup> chicken manure (CM), T<sub>2</sub>= CM + 22.5 Kg mineral N + 21% P, T<sub>3</sub>= CM + 45 Kg mineral N + 21% P, T<sub>4</sub>= CM + 67.5 Kg mineral N + 21%P, T<sub>5</sub>= CM + 90 Kg mineral N + 21%P, T<sub>6</sub>= No fertilizer input

Fertilizer treatment T5 (Chicken Manure + 90kg mineral N + 21%P) had the highest yield mean of 6.3 t ha<sup>-1</sup> (Figure 2) which is higher in relation to what smallholder farmers in Malawi get per hectare. Smallholder farmers yield an average of 2.2 t ha<sup>-1</sup> [20] which correlates to fertilizer treatments T2 (Chicken Manure + 22.5kg

mineral N + 21%P) which had mean yield of 4.1 t ha<sup>-1</sup>. This development is attributed to the good crop husbandry practices and the chicken manure having 4.48% nitrogen (Appendix 2), that was applied together with the inorganic fertilizer for plant's use. Fertilizer treatment T3 ensured judicious use of inorganic fertilizer in attaining an optimal farmer's yield which is in line with what [6] who found that use of poultry manure reduces the amount of inorganic fertilizer used. The use of chicken manure at 4 t ha<sup>-1</sup> only resulted in a grain yield of 2 t ha<sup>-1</sup> which is close to what average smallholder farmers in Malawi get, that is approximately 2.5 t ha<sup>-1</sup> [20] and was significantly different (P<0.05) from T1 treatment where manure was not applied. This finding is supported by [21] who noted that applied manure is a source of soil organic matter which releases nutrients for plants absorption after decomposition and therefore accounts for the manured treatments compared to the non-manured treatments.

**Table 4:** Effect of variety and location on Maize (*Zea mays*. L) Yield and cob weight of Hybrid Maize in Malawi during 2016/17 growing season

Treatment	Yield (kg ha <sup>-1</sup> )	Cob weight (Kg ha <sup>-1</sup> )
<b>Variety</b>		
SC627	4145.0a	2958.0a
SC403	3901.4a	2012.1b
CV	14.19	18.32
LSd (P<0.05)	2.74ns	218.02
<b>Location</b>		
Makoka	4330.0a	2653.8a
Chitedze	3716.3b	2316.3b
CV	14.18	18.31558
LSd (P<0.05)	2.73	218.02

Means with the same letters in the same column under a particular factor are not significantly different at P<0.05.

**Table 5:** Nitrogen level and location interaction effect on maize shoot biomass in Malawi during 2016/17 growing season (Mean±SE)

Treatment	Location	
	Makoka (Kg ha <sup>-1</sup> )	Chitedze (Kg ha <sup>-1</sup> )
T <sub>1</sub>	3524.42 ± 119.07	3471.08 ± 103.07
T <sub>2</sub>	4497.74 ± 51.37	3633.31 ± 63.83
T <sub>3</sub>	8184.39 ± 233.70	7786.61 ± 218.60
T <sub>4</sub>	9573.27 ± 200.38	8527.72 ± 220.91
T <sub>5</sub>	9697.31 ± 141.48	9708.82 ± 136.34
T <sub>6</sub>	2193.98 ± 161.58	1813.32 ± 184.75
CV		6.34
R <sup>2</sup>		0.99

CV= Coefficient of variation,  $\pm$  = Standard error. T<sub>1</sub>= 4 T ha<sup>-1</sup> chicken manure (CM), T<sub>2</sub>= CM + 22.5 Kg mineral N + 21% P, T<sub>3</sub>= CM + 45 Kg mineral N + 21% P, T<sub>4</sub>= CM + 67.5 Kg mineral N + 21% P, T<sub>5</sub>= CM + 90 Kg mineral N + 21%P, T<sub>6</sub>= No fertilizer input. Fertilizer treatment T<sub>5</sub> also produced significantly higher (P<0.05) biomass than other fertilizer treatments. Maize variety SC627 had a higher mean yield of 4.1 t ha<sup>-1</sup> and significantly different (P<0.05) to maize variety SC403 which yielded 3.9 t ha<sup>-1</sup>. The difference is attributed to the genetic make-up of the 2 varieties, as SC627 is a medium maturing variety having a potential yield of 9 t ha<sup>-1</sup> and SC403 maize variety being a medium maturing variety having a potential yield of 7 t ha<sup>-1</sup> [22]. The maize varieties that were grown at Makoka site gave a significantly higher (P<0.05) mean biomass yield of 4.5 t ha<sup>-1</sup> than Chitedze site which had a mean biomass yield of 3.6 t ha<sup>-1</sup>. This difference may be attributed to the relatively even distribution of rainfall at Makoka as opposed to Chitedze which received uneven rains and some sporadic prolonged dry spell which affected plant growth and development. Maize variety SC627 grown at Makoka produced the highest grain yield, cob weight and biomass as compared to maize variety SC403 grown at Chitedze which produced the lowest mean values on both grain and biomass yield. This result could be attributed to adequate fertilizer and evenly distributed moisture supply which were up taken by the plants for metabolic functions as opposed to Chitedze site which had erratic and unevenly distributed rains. This finding is supported by other studies which showed that availability of moisture and nutrients is translated in higher grain, biomass yield and heavier seeds [23] [24].

**Table 6:** Correlation coefficients of agronomic traits of hybrid maize in Malawi during 2016/2017 growing season

	Yield	Biomass	Cob weight
Yield	1.00		
Biomass	0.91***	1.00	
Cob weight	0.34**	0.27*	1.00

Yield = Maize grain yield per ha<sup>-1</sup> \*= Significance level.

Pearson correlation coefficient determination is important in data analysis as it quantifies the relationship between two variables in unit-free form whether there is positive, negative or no relationship [25]. In this study, all the variables were positively correlated with different relationship levels to yield. Biomass showed a strong positively correlated relationship of greater than 75% to the yield. This is attributed to the increased surface area for photosynthesis which ensured steady maize growth and development. Nitrogen acts through expansion of the leaf area as well as increasing leaf area duration which prolongs the active period for photosynthesis if other factors are adequately supplied, resulting in increased biomass and longer grain filling period hence better maize grain yield and larger seeds. The weak correlation between the cob weight to biomass and the grain yield could be attributed to genetic make-up of the maize varieties used as they were not late maturing varieties which focus much on grain filling and not increased cob mass due to short post-anthesis period. The most limiting factor for the study is that the research was done in two sites of Malawi in the same year, hence the need to further do the research in different seasons so as to incorporate the time effect in the study.

#### **4. Conclusion and Recommendations**

The research study was directed at determining an integrated Chicken manure and inorganic fertilizer formulation that ensures: efficient Nitrogen uptake by the maize plant for growth and development, optimal maize grain yield at a reduced cost of production. The results from the study indicated that: Fertilizer treatment T2 produced the best mean heights and girth that were not significantly different ( $P < 0.05$ ) to the other fertilizer treatments that had a higher Nitrogen content i.e. Fertilizer treatment: T3 T4 and T5. Fertilizer treatment T5 (Chicken Manure + 90 kg mineral N + 21P) was found to produce the highest maize mean yield of  $6.3 \text{ t ha}^{-1}$  but T3 [Chicken manure + 45 kg mineral N: UREA (46%N)] fertilizer treatment yielded a much higher mean maize grain yield of  $4.6 \text{ t ha}^{-1}$  which is way high to the smallholder farmers' mean yield of 2.5- 3.0  $\text{t ha}^{-1}$ . SC627 maize variety was observed to have performed well in all the two sites as compared to SC403 in terms of growth and maize grain yield attributes. From the research study that was conducted and based on the conclusion, it is recommended that: Smallholder farmers in Malawi who do not have enough resources should use T3 [Chicken manure ( $4 \text{ t ha}^{-1}$ ) + 45 kg mineral N: Urea 46% N] fertilizer treatment and SC627 maize variety for better maize yield production of  $4.6 \text{ t ha}^{-1}$  to ensure food security at household and National level. Those farmers who would want to grow maize for consumption and a surplus for sale should use fertilizer treatment T5 [Chicken manure ( $4 \text{ t ha}^{-1}$ ) + 90 kg mineral N: UREA 46%N] and SC627 maize variety as it had the highest mean yield of  $6.3 \text{ t ha}^{-1}$ .

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## **5. Appendices**

**Appendix 1:** Mean temperature and rainfall data for Makoka and Chitedze sites for 2016/17 growing season in Malawi

**Table 7**

Site	Parameter	2016			2017						
		Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July
<b>Makoka</b>	Rain fall(mm)	0.70	112.60	176.60	308.9	152.7	200.9	9.80	1.40	7.9	00
	Max temp(°C)	31.60	31.20	28.76	27.41	28.19	26.21	25.68	25.41	23.74	19.34
	Min temp(°C)	17.90	19.43	19.62	19.19	18.88	17.30	16.13	14.34	12.31	8.78
<b>Chitedze</b>	Rain fall(mm)	13.50	3.30	81.60	246.1	489.1	138	70.90	00	00	00
	Max temp(°C)	31.34	29.80	28.90	26.92	27.48	26.96				
	Min temp(°C)	16.66	17.30	19.30	19.05	18.12	17.34				

**Appendix 2:** Chemical analysis of soil samples from Makoka and Chitedze sites during 2016/2017 growing season in Malawi

**Table 8**

Site	pH	%OC	%N	P (ug/g)	K Cmol/kg	Ca	Tex. Class
Makoka	4.8	0.2	0.01	78.8	0.09	0.33	SCL-LS
Chitedze	5.5	1.6	0.10	18	0.09	0.03	SL-SCL
Chicken manure			4.48				

SCL= Sandy clay loam, LS= Loamy soil, SL= Sandy loam