



## **Effects of Spatial Arrangements and Fertilizers on Productivity in Maize (*Zea mays*) and Spinach (*Celosia argentea*) Intercrop**

**Olufunke Olubunmi Olajide<sup>1\*</sup>**

<sup>1</sup>*Department of Crop, Horticulture and Landscape Design, Faculty of Agricultural Sciences, Ekiti State University, P.M.B. 5363, Ado Ekiti, Nigeria.*

### **Author's contribution**

*The sole author designed, analysed, interpreted and prepared the manuscript.*

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### **ABSTRACT**

Maize production falls short of demands in the world because of continuous cropping of a land area, which result into loss of natural soil fertility and decline in yield. This study was undertaken to investigate the performance of maize to organic and inorganic fertilizer and to ascertain spacing for maize-spinach intercrop. The experiment was conducted at the National Horticultural Research Institute, Ibadan. The nutrient sources were farmyard organic manure (derived from household waste materials), and inorganic fertilizer (NPK 15:15:15). These soil nutrient sources were applied at the rate of 100Kg N/ha. The plant spacing used for the maize/spinach intercrop include; 75 x 50 cm, 75 x 75 cm, 75 x 25 cm-sole maize and 25 x 10 cm-sole spinach. Data collected were; plant height, number of leaves, stem girth, leaf area, and yield per cob and fresh weight of spinach. All data were analyzed using the Analysis of variance (ANOVA) and means separated by the least significant difference at 5% probability (LSD, 0.05). F<sub>1</sub>T<sub>1</sub> and F<sub>2</sub>T<sub>4</sub> produced better values for growth and yield parameters than other treatments. The highest value for fresh weight of spinach was obtained at F<sub>2</sub>T<sub>2</sub> (9.30Kg). The results suggested that the application of NPK fertilizer was the best nutrient source for maize production and maize-spinach intercrop should be planted at either 75 x 50 cm spacing, although organic fertilizer is environmental friendly, cheaper and release nutrients contents are slowly, store longer in the soil, thus subsequent planting can still benefit already from previous application.

\*Corresponding author: E-mail: [olubunmi.olajide@eksu.edu.ng](mailto:olubunmi.olajide@eksu.edu.ng);

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## 1. INTRODUCTION

Maize (*Zea mays*) is one of the oldest crops in the world, is the highest yielding grain having multiple uses. Maize is a major crop grown for both human and livestock consumption. It is generally believed to have originated from Mexico. It is one of the most important food grains in the world most especially in the developing countries. It's an amazing energy storing crop which grows up to 4 meters or more depending on varieties. Maize meals provide more calories and vitamin A than rice and wheat in equivalent.

In Nigeria, maize is an important crop as it provides inexpensive nutrition that helps to sustain the rapidly increasing population. Apart from providing the staple diet for the population, it is also an important crop in industrial and livestock production in the country and has become the most important raw material for animal feed [1]. World production of maize is around 790 million tones, providing more than one-third of the calories and proteins in some countries [2] and maize is predicted to become the crop with the greatest production globally, in the developing world by 2025 [3]. It is generally believed to have originated from Mexico but reported for the first time in West Africa in 1498 [4]. Among cereal crops, maize has the highest average yield per ha and remains third after rice in total area and production in the world.

Spinach (*Celosia* species) is a fast-growing annual leafy vegetable, cultivated in southwestern Nigeria [5]. The most commonly cultivated species is *Celosia argentea*, which has its origin in West Africa. Its leaves and young shoots are used in soups and the seed contains significant amount of edible oil [5]. *C. argentea* is used in the treatment of diarrhoea, piles, bleeding nose, disinfectant, inflammation, haematological and gynaecologic disorders in folk medicine [6].

Despite the importance of maize and spinach, their production still fall short of demands because of cultivation of poor-yield varieties, unpredictable weather conditions, pests and diseases, and continuous cropping of a land area and poor soil fertility, which result into decline in yield. Thus, different fertilizers, organic and inorganic are used to improve soil fertility to boost plant production.

Nitrogen (N) is the most important nutrient required for the production of both maize and spinach. Continuous use of inorganic fertilizer often result into number of problems such as leaching, surface water and ground water contamination, soil acidification, reduction in useful microbial communities and increased sensitivity to harmful insects [7]. Thus, there is the need for alternative, organic sources of Nitrogen [8]. Use of organic manures have been known to farmers in early agriculture for their favourable effects on soil, and could be a potential substitute to inorganic fertilizers. The use of organic manure serves as a means of increasing and maintaining soil fertility [9]. Organic manures are sourced from cheap and abundant household wastes [10]. Animal manures, when properly and efficiently applied, ensures sustainable crop productivity by immobilizing nutrients that are susceptible to leaching, because the nutrients contained in manures are slowly released and can be stored for a longer period in the soil. The need to reduce the cost of crop fertilization and improved environmental conditions necessitate the utilization of organic manure. Studies have also shown that crops fertilized with organic manure are more naturally nourished, stored longer and do not show susceptibility to rapid mould and rotting [11]. Also, Organic matter improves soil aeration and water infiltration, and it also improves both water and nutrient holding capacity of soils. They increase water retention by the soil and are important in maintaining soil tilth [12].

Intercropping is a crop management system involving two or more economic species grown together in a production cycle and planted sufficiently close to each other. Intercropping enhance efficient use of available land nutrients, yield stability, soil and water conservation, reduced leaching of nutrients, balanced distribution of labour and higher economic returns and reduces the weed pressure [13].

Much work has been done on the sole cropping of maize [14], spinach [15] and intercropping of either maize or spinach with other crops such as cowpea and cassava [16]. There are limited reports on maize-spinach intercrop, especially in relation to the spatial arrangement and relative plant population densities. Therefore, the present study was carried out to evaluate the effects of farmyard organic manure and NPK 15: 15: 15 fertilizer on the growth and yield of maize-spinach intercrops.

## 2. MATERIALS AND METHODS

### 2.1 Site Description and Experimental Design

The experiment was carried out at the National Horticultural Research Institute (NIHORT) between May and July, 2010 at the Farming Systems Experimental Field, Ibadan (latitude 7°22'N longitude 3°58'E). The experimental design was conducted as a split-plot in a randomized complete block design (RCBD) with three replications. The main plot treatments were two nutrient sources, organic and inorganic manure. The sub-plots treatments were different spatial arrangements, 75 x 50 cm, 75 x 75 cm 75 x 25 cm, sole maize and 25 x 10 cm, sole spinach. Treatment combinations are presented in Table 1. The organic manure was applied one week before planting while the chemical fertilizer (NPK 15: 15: 15) was applied two weeks after planting. The amount of fertilizer applied was calculated based on 100KgN/ha. The maize seeds were planted at the rate of 2 seeds per hole and 4 plants per plot. Spinach seeds (SokoTLV8) were sown at the rate of 2 seeds per hole. Weeding was done manually and insecticide containing lambda-cyhalothrin as active ingredient (Trade name: Karate®) was applied to control insect pests.

### 2.2 Soil Sampling Physical and Chemical Analysis

Top soil (0-15 cm) samples were randomly collected from experimental site, bulked to form a composite sample; air dried and sieved using a 2mm mesh size. Routine analysis as described in [17] for physical and chemical properties were carried out on the soil sample.

### 2.3 Agronomic Analysis of Maize and Spinach

Data collection started at 4 weeks after planting. The number of leaves was taking by counting the leaves present on the two plants tag for sampling and later divided by two to get the average, plant height was measured using tape rule from tip of the plant to base, stem girth was done using Verner caliper to measured the plant width and leaf area was determined by measuring the length and breadth of the leaf. Data were taken weekly. Destructive sampling was carried out at two weeks interval on maize, in which one plant was uprooted, weighed, and separated into leaves, stem and roots. The plant parts were later oven-dried to a constant weight and the value of dry weight was recorded, the fresh weight of spinach were determined at 6 weeks after planting.

Land equivalent ratio (LER): The indicator of the efficiency of intercropping for using the resources of the environment compared with monocropping.

$$\text{The LER was calculated as: } LER = \frac{Y_{AB}}{Y_{AA}} + \frac{Y_{BA}}{Y_{BB}}$$

where:

YAB = yield of crop A (maize) when intercropped with crop B (spinach)

YBA = yield of crop B (spinach) when intercropped with crop A (maize)

YAA = yield from sole planted crop A

YBB = yield from sole planted crop

### 2.4 Statistical Analysis

The recorded data on growth performance of the crops were subjected to analysis of variance

**Table 1. Experimental layout of nutrient sources and spatial arrangement using split-plot**

Designation of treatments	Crop combinations	Spacing (cm)
<b>Organic manure</b>		
*F <sub>1</sub> T <sub>1</sub>	Sole maize	75 x 25
*F <sub>1</sub> T <sub>2</sub>	Sole spinach	25 x 10
F <sub>1</sub> T <sub>3</sub>	Maize/spinach	75 x 50
F <sub>1</sub> T <sub>4</sub>	Maize/spinach	75 x 75
<b>(NPK 15: 15: 15)</b>		
*F <sub>2</sub> T <sub>1</sub>	Sole maize	75 x 25
*F <sub>2</sub> T <sub>2</sub>	Sole spinach	25 x 10
F <sub>2</sub> T <sub>3</sub>	Maize /spinach	75 x 50
F <sub>2</sub> F <sub>4</sub>	Maize /spinach	75 x 75

Asterisk\*: sole planting

(ANOVA) and the means were separated using Duncan Multiple Range Test (DMRT).

### 3. RESULTS

#### 3.1 Soil Analysis

Table 2 shows the values of the physical and chemical properties of the soil sample collected from the experimental site. The soil belongs to the textural class of sandy loam with 812 g/kg sand, 94 g/kg silt and 94 g/kg clay contents. The Nitrogen status of the soil (0.49 g/kg) was lower than the critical value (10-15 g/kg), hence nitrogen fertilization was needed.

#### 3.2 Growth Performance and Yield of Maize

Table 3 shows that the height of maize was affected by the treatments at different weeks of sampling. It was observed that the plant height increased progressively as the sampling week increases. There were no significant differences on plant height in relation to the nutrient sources and spacing. The plant height obtained from F<sub>2</sub>T<sub>4</sub> at 8 weeks after planting (192.60 cm) was significantly higher compared to other treatments. The number of leaves increased till 8 weeks after planting. At 4-5 weeks after planting, there was no significant difference in the number of leaves observed among the plots sampled

**Table 2. Physical and chemical properties of experimental soil**

Physical parameters	Value(g/kg)
Sand	812
Silt	94
Clay	94
Textural class	Sandy loam
Chemical properties	Value(g/kg)
Ph	1.20
Organic carbon	4.80
Total Nitrogen	0.49
Available P (mg/kg)	18.80
Total acidity	1.50
Exchangeable bases	(cmol/kg)
K	0.42
Ca	13.50
Mg	2.50
Na	1.24

**Table 3. Effect of fertilizers and spacing on plant height (cm) of maize (*Zea mays*)**

Treatments	Weeks after planting				
	4	5	6	7	8
*F <sub>1</sub> T <sub>1</sub>	47.60	51.40	87.40	121.30	170.00
*F <sub>1</sub> T <sub>2</sub>	-	-	-	-	-
F <sub>1</sub> T <sub>3</sub>	37.60	42.30	76.00	102.90	150.50
F <sub>1</sub> T <sub>4</sub>	45.90	45.50	86.90	121.90	167.60
*F <sub>2</sub> T <sub>1</sub>	49.00	56.30	90.00	121.00	156.60
*F <sub>2</sub> T <sub>2</sub>	-	-	-	-	-
F <sub>2</sub> T <sub>3</sub>	43.70	53.20	74.70	115.20	169.50
F <sub>2</sub> T <sub>4</sub>	41.90 ns	59.40 ns	107.90 ns	156.00 Ns	192.60 Ns

Asterisk \*: Sole planting, ns: no significant difference, F: Fertilizer, (F<sub>1</sub>= farmyard organic manure, F<sub>2</sub>=NPK 15:15:15 Fertilizer); T: plant spacing, (T<sub>1</sub>=75 x 25 cm, T<sub>2</sub>= 25 x 10 cm, T<sub>3</sub>=75 x 50 cm, T<sub>4</sub>=75 x 75 cm). Mean with different letter in the same column are significantly different at 5% probability

**Table 4. Effect of nutrient sources and spacing on the number of leaves of maize**

Treatments	Weeks after planting					
	4	5	6	7	8	9
*F <sub>1</sub> T <sub>1</sub>	9	10	12	13	15	15
*F <sub>1</sub> T <sub>2</sub>	-	-	-	-	-	-
F <sub>1</sub> T <sub>3</sub>	8	12	13	12	14	14
F <sub>1</sub> T <sub>4</sub>	9	11	13	13	14	15
*F <sub>2</sub> T <sub>1</sub>	10	11	13	13	14	14
*F <sub>2</sub> T <sub>2</sub>	-	-	-	-	-	-
F <sub>2</sub> T <sub>3</sub>	10	10	13	13	15	15
F <sub>2</sub> T <sub>4</sub>	8	9	11	13	14	15
	ns	ns	ns	ns	ns	ns

Asterisk \*: sole planting, ns: no significant difference, F: Fertilizer, (F<sub>1</sub>= farmyard organic manure, F<sub>2</sub>=NPK 15:15:15 Fertilizer); T: plant spacing, (T<sub>1</sub>=75 x 25 cm, T<sub>2</sub>= 25 x 10 cm, T<sub>3</sub>=75 x 50 cm, T<sub>4</sub>=75 x 75 cm). Mean with different letter in the same column are significantly different at 5% probability

**Table 5. Effect of different fertilizers and spacing on cob weight and total yield of maize (Zea mays)**

Treatment	Cob weight per plant (g)	Total Yield per plant(g)
*F <sub>1</sub> T <sub>1</sub>	159.15cd	222.55c
*F <sub>1</sub> T <sub>2</sub>	-	-
F <sub>1</sub> T <sub>3</sub>	171.23bcd	225.96c
F <sub>1</sub> T <sub>4</sub>	99.02d	280.00bc
*F <sub>2</sub> T <sub>1</sub>	106.99d	208.07c
*F <sub>2</sub> T <sub>2</sub>	-	-
F <sub>2</sub> T <sub>3</sub>	280.70a	296.25bc
F <sub>2</sub> T <sub>4</sub>	260.54a	400.43a

Asterisk \*: sole planting, ns: no significant difference, F: Fertilizer, (F<sub>1</sub>= farmyard organic manure, F<sub>2</sub>=NPK 15:15:15 Fertilizer); T: plant spacing, (T<sub>1</sub>=75 x 25 cm, T<sub>2</sub>= 25 x 10 cm, T<sub>3</sub>=75 x 50 cm, T<sub>4</sub>=75 x 75 cm). Mean with different letter in the same column are significantly different at 5% probability

(Table 4). Table 5 shows the yield components of maize plant. There were significant differences in the weight of cobs and total yield produced per plant based on the spacing and nutrient sources applied, treatment F<sub>2</sub>T<sub>4</sub> produced the highest value of 260.54 g and 400.43 g for cob weight and total yield per plant respectively.

### 3.3 Growth Performance and Fresh Weight of Spinach

Treatment F<sub>2</sub>T<sub>2</sub> gave the highest fresh weight of 9.30 Kg in (Table 6), which was significantly higher than other treatments used in the experiment, followed by F<sub>1</sub>T<sub>2</sub> (7.0 Kg), which was significantly different from F<sub>2</sub>T<sub>3</sub> (4.54 Kg), while F<sub>2</sub>T<sub>4</sub> gave the lowest fresh weight (2.10 Kg). In addition, though F<sub>2</sub>T<sub>2</sub> gave the highest value of 92.50 cm and 193.80 cm for leaf area at week 4 and 8 respectively but not significantly different from other treatments in the above weeks of sampling.

### 3.4 Land Equivalent Ratio

Table 8 indicates the land equivalent ratio of maize/spinach intercrop. The LER was more than one (>1) for treatments; F<sub>1</sub>T<sub>3</sub>, F<sub>2</sub>T<sub>3</sub> and F<sub>2</sub>T<sub>4</sub>, thus indicating yield advantage in the different spacing used in the above treatments, and intercropping pattern was more advantageous than sole cropping. The highest value (1.51) was recorded at F<sub>2</sub>T<sub>3</sub> while the lowest value (0.86) was recorded by F<sub>1</sub>T<sub>4</sub>.

## 4. DISCUSSION

Maize production throughout Africa depends solely on fertilizer application, especially for the production of the vegetative part and nitrogen is an important nutrient for the production of maize, thus this nitrogen can be derive from either organic or inorganic fertilizer sources but more importantly from the organic sources because they are environmentally friendly, also improve and enriches the soil fertility status.

**Table 6. Effect of different fertilizers and spacing on leaf area (cm) of spinach**

Treatments	weeks after planting				
	4	5	6	7	8
F <sub>1</sub> T <sub>1</sub>	-	-	-	-	-
F <sub>1</sub> T <sub>2</sub>	63.60ab	101.90ab	151.90abc	139.90abc	145.50ab
F <sub>1</sub> T <sub>3</sub>	65.90ab	112.70ab	105.00bc	116.20abc	179.20ab
F <sub>1</sub> T <sub>4</sub>	84.70ab	105.00ab	168.40ab	167.30abc	169.40ab
F <sub>2</sub> T <sub>1</sub>	-	-	-	-	-
F <sub>2</sub> T <sub>2</sub>	92.50ab	94.03ab	170.80ab	180.50ab	193.80ab
F <sub>2</sub> T <sub>3</sub>	67.20ab	82.20abc	132.60abc	145.10abc	162.60ab
F <sub>2</sub> T <sub>4</sub>	86.10ab	109.50ab	174.50ab	156.20abc	178.40ab

Asterisk \*: sole planting, ns: no significant difference, F: Fertilizer, (F<sub>1</sub>= farmyard organic manure, F<sub>2</sub>=NPK 15:15:15 Fertilizer); T: plant spacing, (T<sub>1</sub>=75 x 25 cm, T<sub>2</sub>= 25 x 10 cm, T<sub>3</sub>=75 x 50 cm, T<sub>4</sub>=75 x 75 cm). Mean with different letter in the same column are significantly different at 5% probability

As regards morphological parameters, the highest value for plant height of maize was obtained at treatment F<sub>2</sub>T<sub>4</sub> (192.60 cm) over the weeks of sampling. This could be attributed to the fact that NPK, being a chemical fertilizer readily released its constituent nutrients especially nitrogen, for plant growth and development. Considering the number of leaves produced a continuous increase was observed until 8 weeks after planting when the plant attained the reproductive stage and senescence set in to cause slight reduction in number of leaves. As the planting spacing increases, and the number of leaf increases, the assimilatory capacity of such plant also increases. Since the stem determines the stoutness of the plant, and tends to carry a significant proportion of total dry matter of the plant; this deposited dry matter is withdrawn at a later stage of growth to support reproductive development.

**Table 7. Fresh weight of Spinach in maize/ spinach intercrop**

Treatment	Fresh weight of spinach (Kg)
*F <sub>1</sub> T <sub>1</sub>	-
*F <sub>1</sub> T <sub>2</sub>	7.0ab
F <sub>1</sub> T <sub>3</sub>	2.13cd
F <sub>1</sub> T <sub>4</sub>	4.90bc
*F <sub>2</sub> T <sub>1</sub>	-
*F <sub>2</sub> T <sub>2</sub>	9.30a
F <sub>2</sub> T <sub>3</sub>	4.54bcd
F <sub>2</sub> T <sub>4</sub>	2.10cd

Asterisk \*: sole planting, ns: no significant difference, F: Fertilizer, (F<sub>1</sub>= farmyard organic manure, F<sub>2</sub>=NPK 15:15:15 Fertilizer); T: plant spacing, (T<sub>1</sub>=75 x 25 cm, T<sub>2</sub>= 25 x 10 cm, T<sub>3</sub>=75 x 50 cm, T<sub>4</sub>=75 x 75 cm). Mean with different letter in the same column are significantly different at 5% probability

In the case of maize yield per plant, it was observed that in most of samples collected, NPK-treated plots with larger spacing gave the highest yield. According to Akintoye et al. [18], the application of N-fertilizer to maize often influences dry matter production by increasing leaf area development and photo- efficiency of the leaf area. Thus, the lowest yield of maize per plot resulting from low leaf area was obtained in organic-treated plot (F<sub>1</sub>T<sub>4</sub>) with 0.76Kg, while the highest was obtained from NPK- treated plot (F<sub>1</sub>T<sub>1</sub>) which was 3.10Kg and there were significant differences among the treatments at 5% level of probability. There were significant differences in the weight of cobs and total yield produced per plant based on the spacing and nutrient sources applied, in which treatment F<sub>2</sub>T<sub>4</sub> produced the highest value of 260.54g and 400.43 for cob weight and total yield per plant respectively. Ball et al. [19] Reported that all the organic fertilizers used performed significantly better than control at P<0.05 in growth parameters. This pattern was likewise recorded for most of the morphological parameter mentioned above. Also, F<sub>2</sub>T<sub>2</sub> gave the highest fresh weight of 9.30Kg, which was significantly higher than other treatments used in the experiment, followed by F<sub>1</sub>T<sub>2</sub> (7.0Kg), which was significantly different from F<sub>2</sub>T<sub>3</sub> (4.54Kg), while F<sub>2</sub>T<sub>4</sub> gave the lowest fresh weight (2.10Kg). These result shows that the organic manure used in this experiment performed very well for the growth of spinach. Accordingly, [20] explained that organic fertilizers are also responsible for the formation of soil aggregates which are very essential in maintaining soil fertility.

The land equivalent ratio (LER) can be used to standardize intercrop yields against the sole

**Table 8. Land equivalent ratio of maize/spinach intercrop**

Treatment	Total yield per plot (Kg)		Land equivalent ratio
	Maize	Spinach	
*F <sub>1</sub> T <sub>1</sub>	3.10	-	-
*F <sub>1</sub> T <sub>2</sub>	-	7.00	-
F <sub>1</sub> T <sub>3</sub>	2.18	2.13	1.09
F <sub>1</sub> T <sub>4</sub>	0.76	4.30	0.86
*F <sub>2</sub> T <sub>1</sub>	2.98	-	-
*F <sub>2</sub> T <sub>2</sub>	-	8.50	-
F <sub>2</sub> T <sub>3</sub>	2.90	4.54	1.51
F <sub>2</sub> T <sub>4</sub>	3.13	1.33	1.21

Asterisk \*: Sole planting, ns: no significant difference, F: Fertilizer, (F<sub>1</sub>= Farmyard organic manure, F<sub>2</sub>=NPK 15:15:15 Fertilizer); T: plant spacing, (T<sub>1</sub>=75 x 25 cm, T<sub>2</sub>= 25 x 10 cm, T<sub>3</sub>=75 x 50 cm, T<sub>4</sub>=75 x 75 cm). Mean with different letter in the same column are significantly different at 5% probability

crop. In this study, the LER values were greater than one for treatments; F<sub>1</sub>T<sub>3</sub>, F<sub>2</sub>T<sub>3</sub> and F<sub>2</sub>T<sub>4</sub>, these implies that those treatments were highly efficient and therefore exhibited higher degree of mutual compensation [21]. This still agreed with the report of Bayu et al. [22] that reported LER in intercropping corn and soybean of to be higher than monoculture.

## 5. SUMMARY AND CONCLUSION

Tropical soils are inherently low in fertility hence the need to supply external nutrient input which may either be from either organic or inorganic sources that are essential to improve and sustain crop production on our soil. Inorganic fertilizers are costly and beyond the reach of poor farmers, on the other hand organic fertilizer is easily available and cheap and the results obtained from organic fertilizer treated plots in some plots are not significantly different from the results obtained from inorganic treated plot. Also the organic fertilizer will be more economical at the long run for increasing crop production by the poor farmers, and takes longer time to release nutrient, hence other crop planted after maize/spinach can still benefit from the organic fertilizer already applied. It could be explained that while the application of inorganic fertilizer has an obvious advantage of immediate release of its nutrient to the soil for plant growth and development, the application of organic fertilizer has its own advantage of enriching the soil organic matter and thereby constituting longer-term benefit to the soil and the plant. Manure application in a given year will influence not only crops grown that year but its residual effects will continue to influence crops in the succeeding years, because

decomposition of the organic matter is not completed within one year [23]. Application of organic materials as fertilizers provides growth regulating substances and improves the physical, chemical and microbial properties of the soil [24].

The results obtained in this experiment also showed that maize under intercropping with spinach did best at wider spacing of 75 x 75 cm and spinach can best be intercropped with maize which is a C<sub>4</sub> plant. The result in treatment F<sub>2</sub>T<sub>2</sub> for fresh weight of spinach can be attributed to the quick response of inorganic fertilizer used in the experiment, compare to the organic fertilizer which usually takes longer time to decompose but in the longer run gives better support to soil and plant and since the LER is greater than one, the intercropping favours the growth and yield of both maize and spinach. The LER greater than one (LER>1.0) has been reported with various maize intercropping experiments [25].

## COMPETING INTERESTS

Author has declared that no competing interests exist.

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