International Scholars Journals

International Journal of Manures and Fertilizers ISSN 2756-3863 Vol. 11 (4), pp. 001-005, April, 2023. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Effect of organic and inorganic fertilizer on sorghum (Sorghum bicolor (L.) Moench and maize (*Zea mays L.*) yield and chlorophyll content

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Accepted 4 January, 2023

The effects of amending soil with organic (poultry manure) and inorganic fertilizer on yield and chlorophyll content of maize (*Zea* mays L.) and sorghum (*Sorghum* bicolour (L.) Moench) was carried out at the Teaching and Research (T&R) Farm of the Obafemi Awolowo University, (O.A.U.) Ile - Ife, Nigeria. The experiment was a randomised complete block design (RCBD), laid out in a split-plot arrangement in the second cropping season of year 2001 and 2002. There were four sources of fertilizer for soil amendment: inorganic fertilizer (IF), mixture of inorganic fertilizer and poultry manure (IFPM), poultry manure (PM) and control (C) (no fertilizer or manure treatment). Each fertilizer source supplied 54 kg N plus 25 kg P_2O_5 and 25 kg K_2O_5/ha. There were significant variability and diversity observed on the two crops due to treatments. Grain yield was highest in sorghum (3.55 kg/ha) and maize (2.89 kg/ha) under IFPM followed by IF treatment for maize (2.33 kg/ha) and PM treatment for sorghum ((3.37 kg/ha). Sorghum and maize had the highest dry matter of 72.3 g/plant and 71.0 g/plant under IFPM at harvest. The effects of PM on the dry matter of sorghum (68.1 g/plant) and maize (61.7 g/plant) were not significantly different (p = 0.05) from that of IF (sorghum 66.1 g/plant, maize 58.7 g/plant). Sorghum also had the highest leaf area (LA) (2752.9 cm^2/plant) and total chlorophyll content of 3.28 mg/g under PM while maize on the other hand had the highest LA (1969.5 cm^2/plant) and total chlorophyll content of 2.63 mg/g under IFPM. In both maize and sorghum, the lowest chlorophyll content occurred in control plot. Drought tolerance measured as percentage chlorophyll stability index (CSI%) was highest under control plots in both crops.

Key words: Maize, sorghum, cultivars, nutrient source, poultry manure, chlorophyll, yield.

INTRODUCTION

In Nigeria, intensive cropping is gradually replacing the traditional shifting cultivation that is associated with long period of fallow but low crop yield. The steady decline in food production due to reduced length of fallow on land prompt farmers to amend the soil with different materials (organic and inorganic) in order to enhance plant growth and increase crop yield (Reijnties et al., 1992; Adepetu, 1997). Sobulo and Babalola (1992), Ismail et al. (1996), Olayinka (1996) and Olayinka et al. (1998) have reported the use of several organic materials especially cow dung, poultry droppings, refuse compost and farmyard manure as soil amendments suitable for increasing crop production particularly among subsistence farmers in West Africa. Among the different sources of organic manure, which have been used in crop production poultry manure was found to be the most concentrated in terms of nutrient content (Yayock and Awoniyi, 1974; Lombin et al., 1992) in the farm. In Nigeria, Fabiyi and Ogunfowora (1992) noted the significant of poultry droppings in the southern part of Nigeria. Mokwunye (1980) and Kotschi et al. (1989) observed that manure application improved the availability of some minerals in the soil and especially the transfer of nutrients from rangeland to the crop plant.

The positive effect of the application of inorganic fertili-

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zers on crop yields and yield improvements had been reported (Carsky and Iwuafor, 1999). There are few reports available on the effects of fertilizers on some traits in the plant that influence yield. Follet et al. (1981) reported that chlorophyll coloration is related to the amount of nutrients absorbed by the plant from the soil. Kaloyereas (1958) and Sivasubramaniawn (1992) related the drought resistance of plants to the chlorophyll stability index that has been employed to determine the thermo-stability of chlorophyll. Organic and inorganic fertilizers applied to the soil supply plant nutrients for crop growth and affect the plant's physiological processes, which serve as important instruments in yield development.

This study was therefore designed to investigate the effects of applications of poultry manure and inorganic fertilizer on biomass production, leaf chlorophyll contents and dry grain yields of maize and sorghum under field conditions.

MATERIALS AND METHODS

The experiment was carried out at the Teaching and Research Farm (T&RF) of the Obafemi Awolowo University, Ile-Ife, Nigeria. Ile-Ife is located on longitude 04^{o} 33^{I} E and latitude 08^{o} 28^{I}N at 244 m above sea level. The soil is a low base status forest soil derived from coarse-grained gneiss and granite parent rocks and is classified as an ultisol (Harpstead, 1973). The field experiments were carried out during the late cropping seasons (August – November) of years 2001 and 2002. The test crops were maize (*Zea mays* L. var. DMR- SR-Y) and sorghum (*Sorghum bicolour* (L.) Moench var. IRAT204). The maize and the sorghum seeds were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria and the National Cereals Research Institute (NCRI), Badegry, Nigeria respectively

The field, which was under fallow for one year was ploughed and harrowed before laying out the plots. The plots were laid out in a split-plot design. The main plot size was 26.25 x 10.75 m while the sub-plot size was 4.5 x 4.0 m. The main plots included (1) control, (2) poultry manure (PM), (3) inorganic fertilizer (IF), and (4) mixture of poultry manure and inorganic fertilizer (IFPM).

The two sub-plots consisted of the two crop types planted at 0.75 x 0.5 m to give a population of 53,333 plants per hectare. Each of the sub-plots except the control received 54 kg N/ha plus 25 kg/ha each of P_2O_5 and K_2O_5 in form of inorganic or organic fertilizer. Each experiment was replicated three times. The poultry manure which contained 0.54% N, 0.16% P and 0.09% K, was obtained from the Poultry Unit of the Obafemi Awolowo University, Teaching and Research Farm. It was applied at the rate of 5.56 t/ha in the sole PM plots in each year. Half this rate (2.78 t/ha) was mixed with inorganic fertilizer, which was equivalent to 50% of the IF, applied in the sole plot as the IFPM treatment. The N, P and K components of each of PM and IFPM were thus calculated to be equivalent to 56 kg N plus 25 kg P_2O_5 and 25 kg K_2O_5 /ha. 20:10:10 N.P.K. fertilizer supplied the same amounts of N, P and K. The treatments were incorporated manually with hoe into the 5 cm depth of soil after broadcasting. Planting of seeds was carried out 24h after incorporation of the treatments (Uhlen and Tveitnes, 1995). Weeds were controlled using a formulated mixture of Atrazine and Metalachlor (Premextra 500 FW) applied pre-emergence immediately after planting at the rate of 51.0 kg a.i./ha and later supplemented with one manual weeding. The seeds of the maize and sorghum were treated with Apron plus 50DS before planting in order to suppress insect attack and fungi transmitted diseases.

Data on grain yield at harvest were obtained from plants in the net rows. Measurements of plant height (PLH), leaf area (LA) above ground dry matter (DM) and chlorophyll content (CHL.) were taken at 30 days after-planting (DAP) (time of vigorous vegetative growth); 50 DAP (time of silking in maize), and 75 DAP and the last sampling was at maturity. The leaf area (LA) was recorded using a portable leaf area meter (LI-COR, MODEL LI-2000C)

Leaf samples from crops in the net rows were harvested for chlorophyll content estimation following the methods of Witham et al. (1971) and Bansal et al. (1999) in which 100 mg fresh leaf was crushed in 20 ml of 80% acetone and the extract centrifuged for 10 min at 1000 rpm. Absorbance of the supernatant was recorded at 645 and 663 nm in a CL-24 spectrophotometer. Chlorophyll content (expressed as mg/g-^{1} of each sample) was estimated according to Bansal et al. (1999) as follow:

Chlorophyll a (mg/g-^{1}) = 12.7 (A663) – 2.69 (A645) x VW

Chlorophyll b (mg/g-^{1}) = 22.9 (A645) – 4.86 (A663) x VW

Total Chlorophyll t (mg/g-^{1}) = [20.2 (A645) – 8.02 (A663) x VW]/1000

Where A = absorbance at the given wavelength, W = weight of fresh leaf sample, V = final volume of chlorophyll solution.

Chlorophyll stability index (CSI) was determined as outlined by Sivasubramaniawn (1992). Two grammes (2 g) of fresh leaf was taken and divided into two lots of one gram each. One lot was stored in room temperature (26^{o}C) and the other put in empty test tube standing in boiling water bath for one hour. The chlorophyll content of the two lots was extracted as described earlier. Grain yield was determined at dry maturity.

Data collected were subjected to analysis of variance (Steel and Torrie, 1980; Gomez and Gomez, 1984). Means were separated using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Table 1 shows the average rainfall, temperature and the relative humidity of the two cropping years. There were more precipitation in 2001 compared to 2002 but the average temperature and the relative humidity were higher in 2002 compared to 2001. This observed trend in weather change may affect the nutrient statue of the soil and hence affect the development of crops. Table 2 shows mean square of the sources of variations. Maize significantly differed from sorghum on all the parameters measured. The effect of nutrient source was highly significant (p = 0.01) on plant height, leaf area and grain yield. The effect of nutrient source on chlorophyll content was slightly significant (p = 0.05). The genotype and nutrient source interaction was highly significant for plant height and grain yield. This is in line with the assertion of Wormer et al. (2001) that plant genotypes differ in their response to changing soil fertility and environmental conditions. This was evident in term of height, leaf area, dry matter, chlorophyll content and dry grain yields. The highly significant (p = 0.01) years by nutrient source suggested that the different years of planting influenced the available nutrient to the crops. This result may be due to the significant weather differences that existed between the two years. The significant crop types x nutrient source interaction suggested the crops differ in their response to nutrient supply that existed within the cropp-

Table 1. Average rainfall, temperature and relative humidity during the growing period of maize and sorghum in 2001 and 2002.

Month	2001					2002				
	No of Days with PPT	Average temp (°C)		Average RH%	Total Rainfall	No of days with PPT	Average temp (°C)		Average RH%	Total Rainfall
		Max	Min				Max	Min.		
AUG.	25	27.8	22.2	70.8	246.1	15	25.2	21.1	85.4	182.0
SEPT.	17	29.2	21.6	71.3	285.3	16	25.9	20.6	82.6	243.0
OCT.	17	30.9	22.3	68.3	252.4	06	29.2	21.6	66.8	166.6
NOV.	05	32.5	22.3	74.2	8.6	02	35.6	21.1	56.4	8.6
DEC	03	34.5	22.0	60.3	3.2	00	35.1	22.1	45.3	00.0

Table 2. The mean squares of treatments on the growth parameters, chlorophyll content and grain yield of maize and sorghum

Sources of Variation	df	Mean square				
		Plant height (cm)	Leaf area (cm)	Dry matter (g)	Total Chlorophyll	Grain yield (ton/ha)
Replication (r)	2	143.07	38.6	56.02	10.8	221.6
Years (Y)	1	160.8	49.4	24.45	12.3	195.4
Error a	2	45.22	27.00	18.01	8.6	48.7
Crop Type (CT)	1	372.15**	532.2**	682.1**	56.3**	1665.3**
YXCT	1	201.6	82.15	57.00	15.4	535.9
Error b	4	55.13	32.61	128.28	10.7	182.3
Nutrient (NS)	3	1496.20**	548.70**	136.93*	35.6*	9782.1**
YXNS	3	260.2	831.5**	47.09	24.8**	880.5
CT x NS	3	4404.6**	154.6	117.42	18.4	3111.6**
Y x NS x CT	3	451.6	335.2	83.39	8.5	782.0
Error c	24	119.9	196.5	44.50	6.77	426.2
Total	47					

** and * indicates significance at 1 and 5% levels of probability, respectively.

Table 3. Effect of nutrient source on growth, chlorophyll content and dry grain yield of maize and sorghum

Nutrient source	Crop types	Plant height (cm)	Leaf area (cm)	Dry matter (g)	Total chlorophyll	Grain yield (ton/ha)	Chlorophyll stability indices (%)
Control (C)	Maize	105.0c	166.0c	37.4c	1.73c	0.74e	87.2a
	Sorghum	108.0c	966.0d	42.5c	1.44c	1.94d	92.5a
Inorganic fertilizer (IF)	Maize	136.6b	1275.5d	58.7b	2.73b	2.33c	38.5c
	Sorghum	136.0b	2109.8c	66.1b	2.12bc	2.98b	43.3c
Inorganic fertilizer + poultry manure (IFPM)	Maize	139.0ab	1969.5c	71.0a	2.63b	2.89b	42.6c
	Sorghum	150.2a	2317.8b	72.3a	2.46b	3.55a	70.0b
Poultry manure (PM)	Maize	138.6ab	1874.2c	61.7b	2.26b	2.08cd	40.3c
	Sorghum	144.3a	2752.9a	68.1b	3.28a	3.37a	60.0b

Data for two cropping seasons.
Means with the same letters within the same column are not significantly different at p = 0.05.
ns = Not significantly different.

ing years.

The effect of nutrient source on the growth parameters of maize and sorghum is shown in Table 3. The nutrient sources significantly (p = 0.05) increased all the parameters measured on each crop over control. Between the two crops, sorghum responded significantly more than

Table 4. The effect of treatments on chlorophyll content of maize and sorghum at the end of the two growing seasons

Nutrient source	Maize			Sorghum		
	Chlorophyll a	Chlorophyll b	Total Chlorophyll	Chlorophyll a	Chlorophyll b	Total chlorophyll
Control (C)	1.46	0.56	1.73	0.99	0.44	1.44
Inorganic fertilizer (IF)	1.46	0.63	2.11	1.46	0.65	2.12
Inorganic fertilizer + poultry manure (IFPM)	1.81	0.80	2.63	2.26	0.96	3.28
Poultry manure (PM)	1.47	0.78	2.27	1.70	0.74	2.46
LSD 5%	0.15	0.08	0.39	0.15	0.08	0.39

maize to the nutrient sources on all the parameters measured. Mixture of inorganic fertilizer and poultry manure (IFPM) significantly improved the plant height (PLH), dry matter (DM) and grain yield of sorghum (150 cm, 72.3 g and 3.55 ton/ha, respectively) compared with maize (1.39.0 cm, 71.0 g and 2.89, ton/ha). This result indicated that IFPM is a better nutrient source compare to PM and IF. This may be due to the fact that IF component of the mixture provided early nutrient to the growing crops during the early vegetative growth stage, while the organic component provided nutrient at the later stage of the crop development. It takes some time for the mineralization. The fact that the effects of IF on the parameters measured were gradually lower ($p = 0.05$) than those of IFPM and PM might be due to the leaching of some of nutrients and the available nutrient being used up during the early vegetative growth stage as the two crops required high nutrient for early growth.

The effects of nutrient source on the chlorophyll component of maize and sorghum are shown in Table 4. The effect of treatment was more pronounced on chlorophyll "a" content of sorghum unlike that of maize where the effects were more on chlorophyll "b" The nutrient sources did not increase chlorophyll "a" content except IFPM. Generally, chlorophyll "a" formed the bulk of the total chlorophyll of the two crops. The effect of IFPM was higher chlorophyll "a" and "b" components in maize while PM affected those of sorghum and this affected the total chlorophyll. This confirmed the earlier suggestion that nutrients were released by IFPM and PM toward the post-anthesis stage. Thus, the nutrients were available to develop the site of photosynthesis, thereby aiding yield development of the two crops.

The chlorophyll stability index (CSI) of maize and sorghum were depressed by nutrient sources (Table 3). The IFPM caused significant higher stability indices on sorghum while IF had the least influence on CSI in both crops. This result indicated that high quality of total chlorophyll did not correspondingly increase CSI. The higher CSI of sorghum than maize observed in this study could partly explain by the higher drought resistance tolerant of sorghum as reported by other workers (Possingharm, 1980; Newcomb, 1999). This was because, under high temperature experienced in drought condition, the chlorophyll molecules of sorghum remained stable, thus its assimilate production remain undisturbed. According to Possingharm (1980) and Newcomb (1999) the addition of N and Mg to porphyrin rings of chlorophyll molecules caused temporary instability of the molecules. This could account for the higher CSI of maize and sorghum in control plots over treated plots.

Conclusion

While significant improvement is usually deserved in the use of organic and inorganic nutrient sources in crop production, the improvement in yield, biomass and chlorophyll due to IFPM suggested that its use in crop production would aid both the vegetative and the post-anthesis development of the crops. Considering the effects of the nutrient sources on the chlorophyll content, there were significant impacts of the nutrient sources on the chlorophyll and this is usually evident in the dark green coloration of such crops and a signal to nutrient efficiency. The effect was further observed to reduce resistance to drought by the crops. It is therefore suggested that for optimum performance of maize and sorghum, IFPM or PM could be used by the subsistence farmers to reduce the high cost of fertilizer. Late season cropping of sorghum should be encouraged as it is more resistant to drought in case of rain failure

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