COMPOST AMENDMENT, ENHANCED NUTRIENT UPTAKE AND DRY MATTER ACCUMULATION IN HEAVY METAL STRESSED MAIZE CROP

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ABSTRACT
Contamination of agricultural lands with heavy metals from industrial activities reduces crop production as a result of poor soil fertility and phytotoxicity. Field trial was conducted to assess the influence of Compost and inorganic fertilizer as well as plant growth stage on growth, nutrient uptake, dry matter accumulation and partitioning in maize crop grown on the battery waste contaminated site. Two types of compost (Mexican Sunflower (MSC) and Cassava peels (CPC) composts) were used for the experiment. These were applied at 0, 20 and 40t/ha to give Control, MSC_{20}, MSC_{40}, CPC_{20} and CPC_{40}. Inorganic fertilizer (F1: NPK; 20:10:10) at 100kgN/ha was used. 0t/ha serves as check. Sampling was done at one month after planting (1MAP), two (2MAP) and at final harvesting. The results showed that maize plants treated with compost maintained a high rate of photosynthesis and progressively accumulated dry matter more than control and inorganic fertilizer treatments. Addition of MSC40, MSC20, CPC40, and CPC20 increased total dry matter accumulation per plant over that of control by 603.0, 190.9, 354.6 and 148.5% at 1MAP and 8764.30, 4864.3, 4957.1 and 2371.4% at 2MAP respectively. Diversion of dry matter was in favour of the vegetative part (leaf) at 1MAP, root formation at 2MAP and stem and seed formation at harvesting. It was also observed that accumulation was highly significant at 2MAP (which was the period of anthesis and grain filling) and at harvesting compared to 1MAP. At each sampling period, highest total dry matter accumulation was recorded in MSC_{40}. F1 treatment, also increased dry matter accumulation at 1MAP by 41.5% but reduced it by 21% at 2MAP compared to control. All the maize plants on F1 and control were uprooted at 2MAP when they started dying back. Compost also increased the concentrations of calcium, magnesium, potassium and phosphorous in the maize plants compared to control with MSC_{40} being superior to other treatments. Nutrients accumulation was significant at harvesting. Phosphorous concentration was high in the seeds of the harvested maize plants than other plant parts. Enrichment with Compost had ameliorative effect on maize grown on Pb contaminated soil and increased nutrient and dry matter accumulation in actively growing maize crop on heavy metal contaminated soil. Assimilate accumulation and partitioning was a function of maize growth stage and soil nutrient status.

Keywords: Maize, Compost and Dry matter accumulation

INTRODUCTION
Plant growth and development are the products of dry matter production and nutrients uptake by plant. However, accumulation and distribution of nutrient elements and dry matter in the plant depend on the plant growth stage, efficiency of the photosynthetic organ, availability of soil nutrient and prevailing environmental conditions. Scott and Brewer, (1980) reported that nutrient accumulation occurs in virtual equilibrium with biomass accumulation. Similarly,

eenvironmental condition such as soil contamination with heavy metals has also been reported to have serious detrimental effects on dry matter production and accumulation of essential nutrients by plants (Zhu, 2001).Salinity stress, according to Zhu, (2001) generally disturbs the uptake and accumulation of essential nutrients. Plant growth and dry matter yield is said to decrease in soil containing high concentrations of heavy metals. Kososbrukhov (2004) observed a considerable decrease in dry weights of plant parts specifically under Pb treatment.

Toxic amounts of heavy metals in the soil have also been reported to exert deleterious effects on photosynthetic pigments and photosynthetic efficiency of growing plants (Maksymiec *et al*., 2007; Gurpreet *et al*., 2012). Pb is said to inhibit chlorophyll synthesis either due to impaired uptake of Mg and Fe by plants (Bruzynski, 1987) or because of increased chlorophyllase activity (Drazkiewicz, 1994). Soil contamination with Pb has also been found to lower nutrient absorption. For example, in *Zea mays,* decrease in the uptake of Ca, Mg, K and P was reported and distribution of these elements within the different plant affected due to the presence of Pb in the soil (Walker *et al*., 1997). The overall distribution ratio of Mn and S changed in favour of root and phosphorus content was found to be negatively correlated with soil Pb (Paivoke, 2002). Nitrate uptake declines in plants under exposure to Pb with a concomitant lowering of nitrate reductase activity and disturbed nitrogen metabolism (Burzynski and Gabrowski, 1984; Paivoke, 2002).

The growth stage or level of plant activity is said to determine plant response to heavy metal toxicity. It is said to affect the amount of nutrients absorbed and dry matter accumulation (Hussain *et al*., 2008). For example, young leaves retain large amount of CHO for growth whereas matured leaves transport most of its newly synthesised carbon. This is because as leaf matures its photosynthetic capacity increases and its activities progressively change from sink to source. Maximum dry matter production must therefore be supplemented by appropriate soil nutrients and favourable environmental conditions. This will ensure regular and efficient ion and water transport system of the plant all of which are needed to complement the assimilated carbon and determine how much of the carbon assimilated by leaf during photosynthesis becomes available for export in form of sucrose.

Beneficial effects of improving soil fertility so as to enhance plant nutrition (i.e. providing the chemical elements that are essential for plant growth and development), ameliorate the effect of Pb toxicity on plant and ecologically restore contaminated soil have been recognized by many authors (Chaney *et al*., 2000; Rennevan *et al*,. 2007; Adejumo *et al*., 2010; 2011 and 2012). Ammendment of contaminated soil with organic manures has been reported to generally increase crop yield on contaminated soil but specific effects of these substances on various phases of plant growth and on nutrient uptake have not been adequately investigated. Moreover, most of the studies have been conducted under greenhouse and laboratory conditions (Kopittke *et al*., 2007; Malecka *et al.,* 2009; Keser and Saygideger, 2010; Gurpreet *et al*., 2012). The research work was carried out to determine the interactions between nutrient additions to heavy metal contaminated soil on the pattern of dry matter partitioning and nutrient uptake by maize crop at different growth stages under field conditions.

MATERIALS AND METHODS

Description of experimental site

The research work was conducted at the Exide battery waste dump-site. The dump-site is located on a large expanse of agricultural land in Kumapayi village of Egbeda Local Government Area in Ibadan, Oyo State, South-Western Nigeria. It is situated on latitude 7^{o}24'N and 4^{o}00'E with elevation of 171m above sea level. It lies within the transitional forest ecosystem of Nigeria. The land has been rendered infertile with its associated phytotoxicity due to the presence of these wastes. Soil on this site has been reported to contain high level of heavy metals especially lead (Pb: 138,000mg/kg, Cu: 482mg/kg, Zn: 1510mg/kg, Cr: 12.3mg/kg and Cd: 41.3mg/kg),which made it unproductive and causing phytotoxity on plants growing on this site. The soil was acidic with low pHvalue of 4.2 and poor in soil nutrients (P: 125mg/kg, N: 0.12%, OC: 1.24%, Ca: 4.28cmol/kg, Mg. 0.96 cmol/kg) (Adejumo *et al*., 2011).

Treatments and planting procedure

Two types of compost were prepared from Mexican sunflower and Cassava peel compost. These materials were mixed separately with poultry manure in ratio 3:1 and left for 12 weeks to decompose using PACT-2 method of composting (Adediran *et al.*, 2001). The treatments include Mexican sunflower compost (MSC) and Cassava peel compost (CPC) both applied at three levels (0, 20 and 40t/ha). NPK fertilizer applied at 100kgN/ha and 0t/ha compost served as checks. The experiment was arranged using Randomized Complete Block Design (RCBD) with four replications. The experimental site was carefully demarcated into 24 plots and three blocks based on the number of treatments. The composts were thoroughly mixed with the soil on the plots receiving treatments after weighing using surface application method and worked into the soil by light hoeing and left for four weeks before planting to allow for nutrient mineralization. The plants were spaced at 75cm between and 25cm within rows. NPK fertilizer was applied to the plots receiving fertilizer treatment at 2 Weeks After Planting (WAP) using line application method.

Determination of dry matter accumulation and distribution

To investigate quantitatively the dry matter accumulation distribution during growth, maize plants were uprooted randomly from each plot at one month after planting (1MAP), 2 months after planting (2MAP) and at harvesting for dry matter accumulation At each sampling period, destructive sampling involving two plants in a row from each plot was employed. The plants were carefully uprooted and separated into different parts. At the post-tasselling (2MAP and at final harvesting), partitioning of plant was into root, shoot, tassel plus husk and grains. The plant parts were cut into small pieces, bagged separately in brown envelopes and oven-dried to a constant weight at 70^{o}C. From these, dry weight of each plant part was obtained. The mean dry weight of each plant part was also determined per treatment.

Plant tissue analysis

At each sampling period, the oven dried samples were later milled and ashed for the determination of nutrient composition at various plant parts following standard procedure (IITA, 1979). For Mg, K and Ca, 1g of milled plant was ashed at 500^{o}C for 6 hours. The ash was then dissolved in 10ml of 2M NHO_3 and filtered into 25ml volumetric flask. The filtrates were made up to the mark and analyzed for nutrient elements (Mg and Ca) concentrations in the plant tissue using Atomic Absorption Spectrophotometer while Flame photometer was used for K. Phosphorus was determined in plant ash using the Vanado-Molybdate method. 0.5 g of the plant material was weighed into a porcelain crucible and ashed in a muffle oven at a temperature of 450 – 500ºC. The ashed sample was removed from the oven after cooling and then wet with 1–2 drops of distilled water and 10 ml of 1:2 dilute HNO_3 added. The crucible was then heated on a water bath until the first sign of boiling was observed. It was removed and allowed to cool. The content was filtered into a 100 ml volumetric flask. The crucible was washed two times with 5 ml distilled water and the solution obtained was filtered. After which 10 ml each of ammonium vanadate and ammonium molybdate solutions were added and the resulting solution shaken thoroughly. A spectrometer (470 mm wavelength) was used to read the standard and sample absorbance value.

Data analysis

Statistical analysis was performed using SYSTAT 11.0 (Systat Software, Inc., Chicago, IL, USA). Differences in nutrient concentrations and biomass of maize parts among treatments (MSC40, MSC20, CPC40, CPC20, FI, and Control), maize parts (leaf, stem, and root), and time (1MAP, 2MAP, and final harvest) were tested using one-way ANOVA, respectively. When a significant difference was detected, then a post-hoc test was carried out using the Tukey HSD test. Significance was defined as $P < 0.05$ for all tests.

RESULTS AND DISCUSSION

Effects of Compost and inorganic fertilizer on the total dry matter yield of maize crop on the heavy metal contaminated field at different growth stages

Compost application progressively increased the dry matter accumulation of maize on the contaminated soil compared to inorganic fertilizer and control. Throughout the sampling period, the maize plant treated with compost had the highest dry matter. Compost effectiveness was however affected by application rate and type. Mexican sunflower compost was more effective than Cassava Peel compost in term of total dry matter production and higher rate of both composts was superior to lower rates. At each sampling period, the highest dry matter was recorded in MSC_{40} followed by CPC_{40}. There was however, no significant difference in the dry matter accumulation of maize plant grown on soil treated with MSC_{20} and CPC_{20}.

On the effect of different growth stages on dry matter accumulation in maize, the results showed that assimilate accumulation is a function of the crop growth stage in maize. The amount of dry matter accumulated at each sampling period varied and it increased progressively from 1MAP to final harvest. The dry matter accumulation at 1MAP was however lower in all the treatments (including control) compared to other months. There was an increase in the total dry matter accumulation from all the treatments at 2MAP. At one month after planting, maize plant grown on soil ammended with MSC_{40} produced dry matter which was eight times higher than that of control and five times higher than that of inorganic fertilizer treatments. The dry mater accumulation of maize plant treated with CPC_{40}, MSC_{20} and CPC_{20} were not significantly different from each other but were higher than control. At 2MAP, the highest dry matter was also recorded in the maize plants grown on soil treated with MSC_{40}, followed by that of CPC_{40} which was not significantly different from the maize plant treated with MSC_{20} while inorganic fertilizer and control treatments had the lowest dry matter accumulation. At harvesting, total dry matter accumulation and grain yield at harvesting was only determined for maize crop on compost ammended soil. Plant grown on the plots that received inorganic fertilizer and control were uprooted totally at 2MAP after they had all dried up. Like previous months, maize crop from MSC_{40} treatment had dry matter accumulation which was superior to other treatments MSC_{20}, $CPC_{20}$and CPC_{40}(Table 1).

Effects of different rates of compost and fertilizer application on dry matter partitioning in different parts of maize plant on the heavy metal contaminated field at different sampling periods

Pattern of dry matter distribution also varied based on sampling period and treatments application. In all the treatments (including control) at 1MAP, diversion of dry matter was generally in favour of leaf which served as strong sink at this growth stage followed by the stem and the lowest were recorded in the root. At 2MAP, the dry matter in the root was higher than other plant parts. This was followed by those of the stem and the leaf while the dry matter in the spikelet and ear were the lowest. At harvesting, dry matter distributions favoured stem and seeds development in all the compost treatments (Fig 1).

Effect of compost application and inorganic fertilizer on nutrient accumulation and distribution in different parts

On the effect of composts and inorganic fertilizer on nutrient accumulation in different plant parts and at different sampling periods, compost generally improved the uptake of nutrients by maize plant on heavy metal contaminated soil compared to control and inorganic fertilizer treatments. Nutrient accumulation and distribution in different parts was also influenced by the rate and type of compost. Higher compost rate performed better than lower rate in terms of nutrient uptake and concentrations. In the leaf, application of higher compost rate enhanced nutrients accumulation more than other treatments. Mg accumulation in maize leaf at 1MAP was increased when the soil was treated with MSC40 followed by CPC40 and CPC20. The lowest concentrations of all these elements were recorded in the control leaf. MSC40 treatment also gave the highest concentrations of all the nutrients tested in the stem except in the case of P where application of inorganic fertilizer enhanced P accumulation in the stem more than other treatments. Among compost treatments, the lowest uptake of Ca and K in the stem occurred in the CPC20 treatment. The concentration of these elements in the root was generally high compared to other parts. P was highly concentrated in the root of maize plant treated with CPC20 and Ca was retained more in the root of maize plant from MSC20 treatment (Table 2). At 2MAP, soil amendment with MSC40 also increased nutrient concentrations and enhanced the diversion of Ca, Mg, K and P to the leaf and tassels more than other treatments. The P concentration in the leaf from this treatment was however not significantly different from that of inorganic fertilizer treatment.(Table 3). The lowest was recorded in the control plants.

Sampling period also had significant effect on the type and concentration of different nutrients in maize plant parts. At IMAP, among the four macronutrients (Ca, Mg, P and K) tested for, the concentration of calcium was the highest in all the plant parts. This was followed by that of phosphorus and Magnesium and the lowest was potassium. Compared to other plant parts, Ca, K and P concentrations in the root were however the highest followed by that of the leaf. Magnesium was more in the stem than other plant parts at this stage. At 2MAP, Calcium concentrations in the root and leaf were reduced compared to its concentrations in these parts at 1MAP. The concentrations in the stem for both months were not significantly different from each other. Similarly, phosphorus concentrations were more in the leaf and stem at 1MAP than at 2MAP but the concentrations were the same in the root for both sampling periods. The trend was the same for Mg except for the concentrations in the stem which was more at 2MAP than 1MAP. Potassium concentrations at 1MAP was also higher than that of 2MAP in all the plant parts (Table 4).

Distribution and concentration of nutrients in the maize plant parts at harvesting on the field.
Plant tissue nutrient concentrations at harvesting were only considered for the plants treated with composts. The mean pattern of distribution of absorbed macronutrients in the maize plant parts on the field shows that magnesium and phosphorous concentrations were high in the seeds of the harvested maize plants and were significantly higher than those of the sheath, root, leaf, stem and cob. The concentrations in the leaf, sheath and root were not significantly different from each other ($P<0.05$). The lowest concentration was however detected in the cob. Calcium was accumulated in the root more than other plant parts. This was followed by the concentration in the leaf. The lowest was detected in the seeds (Table 5).

Overall effect of compost and inorganic fertilizer on the total nutrient accumulation at harvesting
On the effects of treatments on the total nutrient accumulation in the plant tissue at final harvest, the maize plants grown on soil ammended with MSC_{40} had the highest concentrations of Calcium, magnesium, potassium and phosphorous in the maize plants. Application of this compost also increased the concentration of P in the root and enhanced its diversion to the cobs and sheath. Potassium concentrations in the root, stem, leaf, cob and sheath of maize grown on these plots were also the highest. In all the treatments, there was no significant difference in the concentration of K in the seeds.

Magnesium concentrations were the highest in the root. leaf, stem and sheath of the maize plants from the plots that received 40t/ha of MSC and the lowest was recorded in the sheath, root, stem, leaf and cobs of the maize plants treated with the lower rate (20t/ha) of MSC and CPC. The lowest concentration of Mg was recorded in the root and seeds of the maize plants grown on soil ammended with 40t/ha of CPC while the highest was recorded in the seeds of maize grown on the soil ammended with the lower rate of CPC. The seeds of the maize plants grown on soil ammended with the higher rates of MSC and CPC had the highest concentrations of Ca (Table 6).

The findings of this research work which confirmed the effectiveness of compost in enhancing dry matter accumulation and nutrient uptake by maize crop planted on heavy metal contaminated soil more than inorganic fertilizer and control treatments agreed with the reports of Chiu *et al*. (2006) and Adejumo et al., (2010) that compost application increased plant yield in Pb contaminated soils. Application of organic amendments to metal-contaminated soils has been reported to alleviate the deleterious effects of heavy metals and restore the nutritional quality of crop grown on the soil (Sharma *et al*., 2011). This was due to the ability of compost to supply all the necessary nutrients required for biomass production (Adediran *et al*., 2001). The availability of these nutrients most especially magnesium in the compost-ammended soil could have also facilitated the synthesis of photosynthetic pigments (Burzynski, 1987; Murty *et al*., 2005). This probably increased the photosynthetic ability or efficiency of maize plants in compost-ammended plots in form of dry matter production. Lower dry matter accumulation in maize plants from un-ammended soil could be due to Pb toxicity. This has been reported to damage the photosynthetic apparatus due to its affinity for protein N- and S- ligands (Ahmed and Tajmir-Riahi, 1993). By inhibiting enzymes involved in CO_2 fixation, Pb decreases carbon assimilation as well as carbohydrate metabolism and their partitioning in growing plants (Perfus-Barbeoch *et al*., 2002). It has also been implicated for chlorophyll degradation due to increased chlorophyllase activity (Drazkiewicz, 1994). According to Backor *et al*. (2007), elevated levels of heavy metals usually decrease photosynthesis due to their indirect effect on the photosynthetic apparatus, including thylakoids causing damage to light-harvesting complexes and Photosystem II (PS II). Additionally, some heavy metals can replace Mg in the chlorophyll causing reduction in chlorophyll synthesis as a result of inhibition of enzymes involved in its synthetic pathway (Shakya *et al*., 2008). Anything that lowers or prevents the production of sugars in the leaves will also lower nutrient absorption All these were evident in the control plants that showed severe leaf chlorosis, necrosis and stunted growth.

The distribution and accumulation of dry matter also varied based on compost type, rate and plant age. This can be attributed to differences in nutrient concentration of two types of compost used (Adejumo *et al*., 2011) and the disparity in the nutrient and photosynthate requirements of different plant parts at a particular growth stage. The growth stage or level of plant activity according to Ashraf and Hussain (2005) are said to be the major factors affecting the amount and type of nutrients absorbed, its accumulation and distribution in different plant parts. This is because the growth rate of a particular part of the plant determines the amount of nutrient that will be diverted to it. For example diversion of photosynthates was in favour of leaf production at vegetative stage and the trend changed during anthesis.

More importantly, macronutrient accumulation which was favoured in maize crop from compost amended soil more than that of inorganic fertilizer could be attributed to the fact that nutrient uptake by plant depends on so many factors such as pH, soil nutrient status and plant sugar supply (Hussain *et al.*, 2008). All of which were favoured in the compost treated soil. Plants grown in nutrient-enriched soil has been found to accumulate more nutrients than those in nutrient-deficient soil like control plants. The organic matter in the compost according to Stewart *et al*. (2000) acts as a nutrient pool, enhances nutrient cycling, soil cation exchange capacity (CEC) and buffer capacity of the contaminated soil. Organic matter also contains humic acid (HA) and Fulvic acid (FA) which are known as nutrients reservoir and have positive and stimulatory effects on crop growth. Humic substances might have also influenced both respiration and photosynthesis. (Serenella *et al*., 2002). The rise in the pH value of the ammended soil also contributed to the dissolution of macronutrients and their subsequent uptake by maize crop (Walker *et al*., 2004; Chiu *et al*., 2006). When soil pH is extremely low (acidic), some of the macronutrients become unavailable to the plant. If the plant is under stress such as heavy metal contamination, its absorption capacity will also be affected (Fodor, 2002; Poschenrieder and Barcel´o, 2004). Heavy metals have been reported to influence homeostatic events, including water uptake, transport, transpiration, and nutrient metabolism and interfering with the uptake of Ca, Mg, K, and P (Benavides *et al*., 2005). High Pb concentration in nutrient deficient soil as reported by Malkowski *et al*. (2002) can also cause leakage of nutrient ions from root cells thereby lowering the nutrient concentration in plants grown on un-ammended soil. High concentration of heavy metal ions such as was reported for this contaminated soil (Ogundiran and Osibanjo 2008; Adejumo *et al*., 2011) could also disturb the uptake and accumulation of essential nutrients (Zhu, 2001). In most cases Pb blocks the entry of cations

(K^+, Ca , Mg, Mn, Zn, Cu, Fe $^{3+}$) and anions (NO_3^-) in the root system (Pallavi and Dubey, 2005). It physically blocks the access of many ions from absorption sites of the roots (Godbold and Kettner, 1991) and causes imbalance of mineral nutrients in growing plants. Competition at absorption site between different elements and their ionic size and charges also affect the uptake of these elements. For example, both calcium (Ca++) and magnesium (Mg++) are cations with two charges. Magnesium is said to have a smaller size which tends to make it more active and compete more effectively for negative charges than calcium. If Ca and Mg are competing for absorption it is more likely that Mg will be taken up (Robert, undated). Also, on the effect of ion size, phosphorus, for example, exists in the soil environment as a negatively charged orthophosphate ion (HPO4-) which has the same size as the positively charged zinc ion (Zn++). If there is an excess of orthophosphate in the soil, a zinc deficiency can result because of the competition between these two elements. This probably was responsible for higher P concentration observed in maize plants grown with MSC.

The nutrients concentration in the maize tissue at 1 MAP which was generally higher than that of 2MAP might be attributed to the availability of these nutrients in the soil medium at this sampling period most especially in compost ammended plots which in turn made nutrients available for plant uptake. The reduction at 2MAP could be due to depletion in the growing medium partly due to leaching or uptake by plant and conversion of the absorbed nutrients into plant metabolites or building products. For example, the increased biomass and nutrient accumulation as well as resistance to lead toxicity observed in maize crop from amended soil based on the previous reports was said to be due to the availability of nutrients in the soil which increases their concentration in plant tissue and stimulate the synthesis of more biomolecules such as phytochelatin and Glutathione which have been implicated in metal detoxification ((Wang *et al*., 2011; Hossain *et al*., 2012). Organic and Amino Acids have also been implicated in a range of processes, including differential metal tolerance, metal transport through xylem and vacuolar metal sequestration (Shah and Nongkynrih, 2007).

CONCLUSION

The results showed that compost ammendment and plant age contributed to dry matter and nutrient accumulation in maize crop grown on heavy metal contaminated soil. Maize plants treated with compost maintain a high rate of photosynthesis on contaminated soil and accumulated dry matter more than control and inorganic fertilizer treatments. Compost enhances the uptake of nutrient elements from the surrounding nutrient solution with a corresponding increase in physiological processes. Enrichment with compost also increased the sink strength of actively growing maize crop. High nutrient and dry matter accumulation at 2 and 3 months after planting suggested that assimilate and nutrient accumulation is a function of the crop growth stage in maize.Tolerance to salt stress, in compost treated plants may be related to plant ability to prevent heavy metal entry in the presence of nutrient ions.

Table 1: Effects of different rates of compost and fertilizer application on the total dry matter yield of maize plant on the heavy metal contaminated field at different sampling periods

Treatments	1MAP	2MAP	HARVESTING
CONTROL	3.1c	1.4d	0.0e
MSC20	9.6b	69.5b	108.9c
MSC40	23.2a	184.1a	174.4a
CPC20	8.2b	37.4c	87.6d
CPC40	10.5b	70.8b	133.0b
F1	4.8c	1.1d	0.0e

Means followed by the same letter on the same row are not significantly different from each other at P<0.05 DMRT
MSC = Mexican Sunflower Compost, CPC = Cassava Peels Compost and F1 = Inorganic fertilizer.

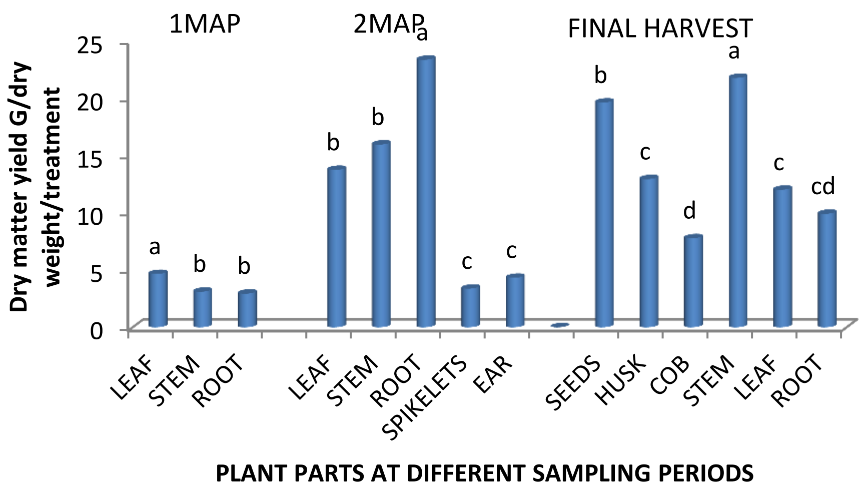

Fig 1. Dry matter partitioning in maize parts at different sampling periods

Table 2: Effect of compost application and inorganic fertilizer on nutrient accumulation and distribution in different parts at 1MAP

Treatments	Ca (mg/kg)			Mg (mg/kg)			P (mg/kg)			K (Cmol/kg)		
	L	S	R	L	S	R	L	S	R	L	S	R
CONTROL	170.0c	1915.8d	1835.0d	126.5d	138.0 d	142.3c	145.5 b	129.5e	333.0c	6.3c	6.3f	16.0d
F1	291.5c	2092.9d	2562.5cd	444.5d	164.0d	822.9bc	2750.0 a	2718.0a	3011.0b	13.5bc	12.1e	19.4d
MSC20	2512.8b	3325.0b	16196.0a	877.5c	424.5b	817.9bc	2438.5 a	2448.5ab	1952.0ab	67.0 a	33.7b	57.5b
MSC40	3434.4a	3676.5a	8818.9b	2667.1a	814.0a	2562.5a	3102.5a	1949.5bc	2801.0ab	52.3ab	38.6a	62.0a
CPC20	2377.5b	1246.5e	2662.8cd	1900.0 b	290.0c	2047.1ab	2443.0a	1701.0cd	3735.0a	51.2ab	19.2d	30.4c
CPC40	3287.6a	2900.0c	3684.2c	2122.1b	242.3cd	798.8bc	2595.0a	1130.0d	1604.0ab	81.1a	26.7c	9.4e
LSD	260.04	335.2	1672.0	413.39	105.63	1398.2	777.38	571.44	3224.8	38.9	4.0	4.4

Means followed by the same letter in the same column under different plant parts are not different from each other (P<0.05)
F1 = Inorganic fertilizer
MSC20= Mexican sunflower compost at 20t/ha, MSC40= Mexican sunflower compost at 20t/ha, CPC20= Cassava peel waste compost at 20t/ha
CPC40= Cassava peel waste compost at 20t/ha, L = Leaf, S = Stem, R= Root

Table 3: Effect of compost application and inorganic fertilizer on nutrient accumulation and distribution in different parts at 2MAP

Treatments	Ca (mg/kg)				Mg (mg/kg)				P (mg/kg)				K (Cmol/kg)			
	L	S	R	T	L	S	R	T	L	S	R	T	L	S	R	T
CONT	553.5c	1625.8d	3815.0bc	0.00e	128.5c	280.0bc	243.5c	0.0c	166.0d	148.5d	214.5e	0.0b	9.0e	12.8ab	9.8b	0.0d
F1	466.0c	3710.8b	3850.5bc	0.0e	501.1b	323.3bc	342.5c	0.0c	1299.0a	2251.0a	656.0de	0.0b	12.7ed	9.6b	8.3b	0.0d
MSC20	1925.0a	4790.0a	3456.5c	425.0d	1143.0a	670.0a	637.0ab	1374.0b	956.0bc	838.5bc	1668.0c	1785.5a	48.2b	10.9b	31.9a	12.8c
MSC40	1933.3a	1690.9d	4751.5ab	1474.0a	1339.0a	475.0ab	775.8a	2215.0a	1545.5a	1292.0b	3732.0a	2630.0a	68.0a	16.4a	29.6a	33.2b
CPC20	906.1b	2114.0 c	1724.5d	619.5c	797.8b	119.9c	564.4b	1219.0b	1036.5ab	651.5cd	1004.5d	2381.0a	35.2c	9.8b	31.5a	31.9b
CPC40	940.8 b	1375.0d	5443.8a	1047.0b	685.5b	516.1ab	775.5a	1325.0b	708.5cd	921.0bc	2384.5b	2468.5a	19.2d	16.2a	25.3a	55.6a
LSD	1347.5	347.46	1051.6	156.7	137.7	250.5	164.9	377.5	148.8	631.6	529.5	1073.1	9.1	4.9	11.2	2.3

Means followed by the same letter in the same column under different plant parts are not different from each other (P<0.05)
MSC20= Mexican sunflower compost at 20t/ha,MSC40= Mexican sunflower compost at 20t/ha, CPC20= Cassava peel waste compost at 20t/ha
CPC40= Cassava peel waste compost at 20t/ha, F1 = Inorganic fertilizer, L = Leaf, S = Stem, R= Root, T = Tassels

Table 4: Effect of sampling period on nutrient accumulation and distribution in different parts

Element	LEAF 1MAP	STEM	ROOT	LEAF	STEM 2MAP	ROOT
Ca (mg/kg)	3345.6ayA	2526.1azA	5959.9axB	2650.4ayB	2551.1ayA	3840.3axB
P (mg/kg)	2245.8bxA	1679.4byA	2239.3bxA	951.9bzB	1017.1byB	1609.9bxB
Mg (mg/kg)	1356.3cxA	345.5czA	1198.6cyA	765.8cxB	397.4cyA	556.4czB
K (cmol/kg)	45.2dxA	22.7dyA	32.4dxA	32.0dx B	12.6dzB	22.7dyB

Means followed by the same letter in the same column for each plant parts are not different from each other (P<0.05) a, b, c, d were used to show the differences between the mean concentrations of the four elements in each plant part for each month

x, y, z were used to show the differences between the mean concentrations of the four elements in each plant part for each month. A, B were used to show the difference between the concentrations of the elements in different plant parts at 1MAP and 2MAP; MAP = Month After Planting

Table 5: Distribution and concentration of macronutrients in the maize plant parts at harvesting on the field.

Plant parts	Ca (g/kg)	Mg (g/kg)	K (cmol/kg)	P (g/kg)
Seeds	0.3f	1.1a	22.4c	3.0a
Leaf	2.6b	0.9b	41.6a	1.7b
Stem	1.2c	0.6c	36.0b	0.8d
Root	4.2a	0.5d	20.9c	1.8b
Sheath	1.4d	0.3e	36.6b	1.2bc
Cob	1.1e	0.5d	15.4d	0.9c

Means followed by the same letter in a column for the treatments and maize plant parts are not significantly different from each other at P<0.05.

MSC20= Mexican sunflower compost at 20t/ha

MSC40= Mexican sunflower compost at 20t/ha

CPC20= Cassava peel waste compost at 20t/ha

CPC40= Cassava peel waste compost at 20t/ha

Table 6: Effect of treatments on the concentration of different nutrients in the maize plant parts at harvesting

Treatments	Ca	Mg	P	K Cmol/kg	Ca	Mg	P	K Cmol/kg
	→	mg/kg	←		→	mg/kg	←	
		LEAF				STEM		
MSC20	2975.0a	983.1ab	1536.0a	29.6	2206.3ab	430.0a	813.0b	25.6b
MSC40	2762.5a	1077.5a	1801.0a	40.3	3084.4a	595.0a	552.5c	24.8b
CPC20	2409.5a	219.0c	1334.5a	22.3	1709.1bc	301.9a	743.5bc	22.4b
CPC40	2365.6a	320.0bc	1934.5a	32.8	987.5c	422.5a	1041.0a	35.2a
		ROOT				SHEATH		
MSC20	1534.5b	406.60ab	1185.50b	11.96a	1143.8b	260.6a	1398.0a	24.0a
MSC40	11893.8a	533.10a	4251.50a	18.83a	2375.0a	304.0 a	2047.0a	30.8a
CPC20	1461.8b	86.90b	658.50b	15.99a	1253.1b	228.1a	680.0b	23.2a
CPC40	1700.0b	364.40ab	903.50b	15.98a	981.3b	219.4a	734.0b	32.0a
		COB				SEEDS		
MSC20	910.50c	530.40a	944.00a	7.99c	300.00a	830.00a	3240.50a	17.59a
MSC40	808.75d	307.30a	1168.50a	15.98a	375.00a	697.50a	3220.00a	16.78a
CPC20	1098.00b	344.00a	455.00b	7.99c	253.13a	890.00a	2330.00a	16.15a
CPC40	1400.50a	168.50a	914.00a	14.38b	350.00a	742.50a	3267.51a	16.78a

Means followed by the same letter in the same column are not different from each other (P<0.05)

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