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Impact of Plastic Enriched Composting on Soil Structure, Fertility and Growth of Maize Plants

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Abstract: The impact of plastic enriched composting on soil structure, fertility and growth of maize (*Zea mays* L.) was examined in this study. A completely randomized blocked design (RCBD) consisting of five treatments *viz.,* A (Control, untreated soil), B (0.83% treatment level), C (1.67% treatment level), D (2.50% treatment level) and E (3.33% treatment level) with three replicates each was used. The result of the physico-chemical parameters of the soil revealed that the addition of plastic granules to the soil resulted to increase in the total organic carbon content and bulk density of the soil. However, other nutrient elements of the soil were not affected. Among the treatments, there was no significant difference (P<0.05) on the germination of *Zea mays* seedlings. The result of impact of plastic on the growth showed that the higher the plastic granules the more its negative impact on *Zea mays* growth. A (36.51 ± 1.30 cm) had the highest growth while the least growth was observed in D (28.50 ± 0.74 cm) and E (28. 78 ± 1.64 cm) treatments after eight weeks of planting.

Key words: Plastics · Biodegradation · Soil fertility · *Zea mays*

INTRODUCTION

Over the past decades there has been a steady increase in the use of plastic products resulting in a proportionate rise in plastic waste in the environment. Plastics have gained widespread use in food, clothing, shelter, transport, construction, medical and recreation industries [1]. The widely use of plastics, can be attributed to their properties which includes low cost, lightweight, extremely durable, relatively unbreakable and aesthetic values. Plastics are composed of petroleum-based materials called resins (e.g. polyethylene and polypropylene)-materials that are resistant to biodegradation [2]. Because of this resistance, plastics that are released into the environment or disposed in landfills tend to persist at steady state in the soil and cause significant ecological problems [3].

In traditional African society, with lower population figures, the native leaves were used in wrapping most of the needed materials [4]. But the challenges of ever increasing population have made Nigerians to learn how to use fairly improved means of wrappers such as polyethylene bags. Also other factors including population growth rate, increasing urbanization, industrialization and economic growth has brought about the phenomenal increase in the volume of wastes generated daily in the country [5]. Polyethylene are currently being used in all forms and shades in Nigeria as wrappers ranging from biscuit, ice-cream, table water, salt, bread and tapes (audio and video) to mention but a few [6]. Polyethylene bags are used virtually in all shopping centers, homes markets, restaurants and farms in Nigeria [7].

In Nigeria, drinking water is sold in plastic bottles and sachets. The public has developed a strong taste for such water since they are portable and can easily be carried from one place to another. There is also a perception that such bottled and sachet water are cleaner and more mineralized than tap water. After gulping down the liquid content, these bags are discarded indiscriminately thereby littering the whole environment. They then collect around the city, choking gutters, threatening small animals, polluting beaches and damaging the soil. When the plastic solid waste is present in soil for long periods, it reduces soil fertility and prevents the growth of plant life and thus, poses environmental problems [8].

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Soil structure has an important influence on soil erosion, water intake and crop growth. A dispersed or compact soil has a low infiltration rate. A stable granulated soil will permit rapid water intake, drainage, aeration and beneficial microbial activity, crops grown in it will respond well to favourable moisture, fertility and good cultural practices [9]. The different groups of soil biota play an important role in establishing a stable structure, especially in soils, which are poor in stabilizing media of physico-chemical nature [10]. Among the factors that can severely limit the biological activity and influence on structure are shortage of substrate supply and unfavourable environmental conditions. The addition of readily decomposable substrate causes a rapid stimulation of soil microflora and this is accompanied by a significant increase in aggregate stability [11, 12, 13].

Soil fertility may be defined as the capacity of the soil to support the growth of plants on sustained basis under given conditions of climate and other relevant properties of land. Low soil fertility inevitably leads to low agricultural productivity [14]. Soil organic matter is a major source of plant nutrients, improves physical properties of soil, such as soil porosity, structure and water-holding capacity [15, 16]. The extent to which organic matter contributes to soil quality depends on factors such as organic material composition, soil fauna activities and environmental conditions [17-19].

A lot of research works have focused majorly on solid waste generation and disposal in Nigeria cities [20, 6]. Likewise much work has been done on various mode of biodegradation of plastics including isolation of plastic degrading microorganisms [2, 21-23]. However, very little has been done in the area of impact of plastic on soil properties and productivities. Researchers worked on impact of xenobiotics on soil biological activity 3]. The present study examined the impact of plastic enriched composting on soil structure, fertility and growth of maize plants.

MATERIALS AND METHODS

The Study Area: The study was conducted at Igbinedion University Okada, Edo State, Nigeria. The study area is located at latitude 06° 43' N and longitude 05° 19' E. The mean minimum and maximum temperatures of the area are 27°C and 31°C, respectively. The area experiences bimodal patterns of rainfall (April-July) and (September-November) with short spell in August. The total annual mean rainfall ranges between 1700 to 2000 mm.

Experimental Design: The experiments were carried out from July to November, 2010. A randomized complete block design (RCBD) with three replicates was used to assess the impact of plastic enriched composting on soil structure, fertility and growth of maize plant.

The plastic type used was polyethylene (PE) granules (resins). The polyethylene granules were obtained from Eleme Petrochemical Company, Port Harcourt, Nigeria. The plastic were further grounded to reduce the particle size. The experiment was consisted of five (5) treatments and replicated thrice, amounting to an aggregate of 15 experimental buckets. Each bucket has 10 liters capacity and perforated at the base and set out on the field.

The treatments were:

- A = Control (untreated soil)
- B = 0.83% treatment level, (50 g of plastic granules to 6 kg of soil sample)
- C = 1.67% treatment level (100 g of plastic granules to 6 kg of soil sample)
- D = 2.50% treatment level (150 g of plastic granules to 6 kg of soil sample)
- E = 3.33% treatment level (200 g of plastic granule to 6 kg of soil sample)

The maize seeds used for this study were collected from Department of Crop Science, Faculty of Agriculture, University of Benin, Edo State, Nigeria. Seed viability test was carried out prior to planting of the maize seed by floatation method as described by [25].

Ten healthy and uniformly sized maize seeds were planted in each experimental unit and germination was monitored at 3rd, 4th, 5th and 6th days after planting. Three maize seedlings per each experimental unit were used to monitor the growth parameters of maize, which include percentage germination, plant height and stem girth. The data for growth parameter were collected every two weeks for eight weeks.

Soil Analysis: All the soil samples were prepared as described by [24]. The soil samples were collected in plastic bags and tagged before transferred to the Laboratory. In the Laboratory, soil samples were spread out on a plastic tray and kept on the Laboratory bench to air dry. The air-dried samples were then ground with mortar and pestle and passed through a 2mm sieve before analysis.

Physico-chemical characteristics of soil samples were analyzed before and after the experiment. The parameters determined includes, pH, total organic carbon (TOC), sand, silt and clay composition, bulk density; total porosity, nitrogen and phosphorus content, cation exchange capacity (CEC).

Data Analysis: The data generated were subjected to analysis of variance (ANOVA) and Duncan's Multiple Range (DMR) test was used to establish significant difference among the treatments at 5% confidence unit using SPSS (version 17.0) computer statistical package.

RESULTS AND DISCUSSION

Soil Analysis: The result of soil analysis before and after the experimental period is presented in Table 1. The particle size analysis of the soil showed that the soil is loamy sand with 74.57% sand, 3.69% silt and 21.74% clay particles. The values of organic carbon (0.58%), N (0.056%), P (26.36 ppm), K (0.20 mol/kg) and other exchangeable bases (Na^{2+}, Ca^{2+} and Mg^{2+}) were low. These values showed that the experimental soil is low in fertility. The pH value (5.20) showed that the soil is acidic with base saturation of 20.19%.

Percentage Germination of *Zea mays*: Percentage seed germination of *Zea mays* was monitored after the 3rd, 4th, 5th and 6th day after planting (Table 2). After 4 th day of planting, seed germination was observed in all the treatments (Table 2). The analysis of the results showed that there was no significant difference among the treatments throughout the germination period.

***Zea mays* Height:** The effect of plastic enriched composting on plant height is presented in Table 3. At 2nd weeks after planting, treatment B had highest height value (14.33cm). This was followed by treatment A, which shows no significant difference (P=0.05) from treatment B. Treatment C, D and E were significantly affected ($P \leq 0.5$). At 4th weeks after planting, treatment A had the highest value (24.78cm) which was not significantly different (P=0.05) from treatment C but significantly better than treatment D. At 6th weeks after planting treatment A (29.34) was significant better than treatment D, while there was no significant difference between it and treatment B (27.03). At 8th weeks after planting, treatment A (36.51cm) was not significantly different from treatment B (35.50) and treatment C (34.28), while treatment D (28.50) and treatment E (28.78 cm) are significantly affected ($P \leq 0.5$).

Stem Girth: Treatment A plants had the widest diameter value (3.22 cm) while *Zea mays* in treatment E had the least stem girth diameter value (2.82 cm) 8th weeks after planting.

The results of the soil particle size shown in Table 1 revealed that the soil sample used in this experiment was a loamy soil. The low base saturation of 20.19% revealed that the soil is an ultisol. The soil is acidic as reflected by its pH value before the experimental period.

Table 1: Physico-chemical characteristics of soil

Treatments (% conc./6kg of soil)		Parameters														
		pH (in H_2O)	Org. C (%)	N (%)	P (ppm)	Mg^{2+} (Cmol/kg)	Base Saturation (%)	Bulk density (%)	Total porosity (%)	Sand (%)	Silt (%)	Clay (%)	Ca^{2+} (Cmol/kg)	K^{+} (Cmol/kg)	Na^{2+} (Cmol/kg)	CEC (Cmol/kg)
Before trial		5.20	0.58	0.056	26.36	0.60	1.40	0.20	0.13	10.50	20.19	1.44	0.46	74.57	3.69	21.74
After trial	A	5.85	0.26	0.061	27.11	0.58	1.46	0.29	0.12	10.53	23.27	1.47	0.45	74.55	3.97	21.48
	B	5.93	0.54	0.058	25.79	0.68	1.38	0.25	0.13	10.21	23.22	1.58	0.40	74.54	3.63	21.83
	C	5.90	0.78	0.062	26.12	0.66	1.45	0.27	0.16	11.03	23.03	1.61	0.39	74.61	3.65	21.74
	D	5.91	0.96	0.063	25.98	0.65	1.43	0.23	0.17	10.67	23.24	1.63	0.38	74.59	3.71	21.70
	E	5.79	1.24	0.057	26.01	0.67	1.39	0.21	0.15	10.53	23.27	1.66	0.37	74.55	3.68	21.72

Table 2: Effects of plastic enriched composting on *Zea mays* germination

Treatments	Germination (%)			
	3rd	4th	5th	6th
A	0.0a ± 0.00	60.0a ± 5.77	93.3a ± 3.33	100.0a ± 0. 0
B	0.0a ± 0.00	56.7a ± 3.33	90.0a ± 6.67	100.0a ±0.00
C	0.0a ± 0.00	53.3a ± 5.67	86.7a ± 3.33	96.7a ± 3.33
D	0.0a ± 0.00	60.0a ± 5.77	80.0a ± 0.00	100.0a ± 0.00
E	0.0a ±. 00	56.7a ± 3.31	83.3a ± 5.77	93.3a ± 3.33

Values with the same letter in the column are not significantly different from one another at 5% level of probability. ± Standard error, n = 3.

Table 3: Effecs of plastic enrached composting on *Zea mays* height (cm)

	Weeks After Planting			
Treatments	2nd	4th	6th	8th
A	$14.33^{a} \pm 0.37$	$24.78^{a} \pm 1.25$	$29.34^{a} \pm 1.31$	$36.51^{a} \pm 1.30$
B	$14.67^{a} \pm 0.25$	$20.80^{b} \pm 0.90$	$27.03^{ab} \pm 0.70$	$35.50^{a} \pm 0.73$
C	$12.56^{b} \pm 0.49$	$22.78^{ab} \pm 0.87$	$25.18^{b} \pm 0.77$	$34.28^{a} \pm 0.75$
D	$12.33^{b} \pm 0.36$	$17.12^{c} \pm 1.33$	$21.80^{c} \pm 0.77$	$28.50^{b} \pm 0.74$
E	$12.56^{b} \pm 0.34$	$20.84^{b} \pm 1.58$	$24.57^{b} \pm 0.90$	$28.78^{b} \pm 1.64$

Values with the same letter in the column are not significantly different from one another at 5% level of probability. ± Standard error, n = 9.

Table 4: Effect of plastic enriched composting on stem girth (cm) of *Zea mays*.

	Weeks After Planting			
Treatments	2nd	4th	6th	8th
A	$2.00^{a} \pm 0.05$	$2.42^{a} \pm 0.07$	$2.88^{a} \pm 0.11$	$3.22^{a} \pm 0.07$
B	$1.87^{ab} \pm 0.04$	$2.22^{b} \pm 0.08$	$2.74^{ab} \pm 0.11$	$3.13^{ab} \pm 0.10$
C	$1.79^{bc} \pm 0.06$	$2.44^{a} \pm 0.87$	$2.89^{a} \pm 0.77$	$3.08^{ab} \pm 0.07$
D	$1.68^{c} \pm 0.05$	$2.12^{bc} \pm 0.06$	$2.78^{ab} \pm 0.05$	$2.97^{bc} \pm 0.06$
E	$1.53^{d} \pm 0.33$	$2.02^{c} \pm 0.04$	$2.60^{b} \pm 0.05$	$2.82^{c} \pm 0.06$

Values with the same letter in the column are not significantly different from one another at 5% level of probability. ± Standard error, n = 9.

The addition of plastic granules resulted to increase in the total organic carbon content of the soil relative to the control. However, other nutrient elements of the soil were not affected by the addition of plastic granules. This could be because of the inert property of plastic in soil. Although, plastic is an organic material, it tend to persist in the soil cause significant ecological problems [26]. Furthermore, the bulk density of the soil was increased while the total porosity was reduced. This is in accordance to the findings of [3] who reported that the addition of granular polythene reduced the soil pore size. [27] also reported that high bulk density causes reduction in water infiltration into the soil, reduced aeration and poor penetration which adversely affect the crop yield. The result on seed germination (Table 1) showed that there was no significant difference in percentage seed germination among the treatments. Contrarily to the report of [28], no germination was observed in all treatments after 3 days of planting. This could be attributed to various factors that might include environmental condition, physico-chemical properties of soil and variety of maize used for the study. The results presented in Table 3 and 4 indicate that the higher the level of the plastic granule in the soil, the more its negative impact on the plant growth. The growth and yield of plant had been reported to be a factor of nutrient availability in the soil [29]. [30] Pointed out that apart from nutrient availability, addition of organic manure also increased porosity and moisture content of soil that enhances root growth and water intake of the plant. However, addition of polythene granules reduced soil pores size, which may have negative effect on the nutrient intake by the root of plant. [31] Reported that the amendment of soil with natural polymer (Wool and hair waste) significantly improved soil fertility. Polythene being a synthetic polymer is not accessible to biodegradative enzyme of soil microflora [32].

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