



(RESEARCH ARTICLE)



Bioconversion of waste paper into soil conditioner and its effect on plants growth and microbial population of the soil

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Abstract

This research work focused on bioconversion of waste paper into soil conditioner and its effect on plants growth and soil microbial population. The effects were studied for 21 days and the number of seeds germinated and their height were measured at 3 days interval. Percentage (%) seed germination across the samples was 100 %. The height of the plants in soil treated with composted waste paper ranged between 80 ± 0.98 mm and 643 ± 1.76 mm that of control soil ranged between 70 ± 1.98 mm and 503 ± 1.67 mm. The result for the microbial analysis revealed a total bacterial count range from 4.0 ± 1.01 to $6.9 \pm 1.03 \times 10^5$ cfu/g for soil samples treated with composted waste paper and 5.0 ± 0.78 to $6.1 \pm 1.29 \times 10^5$ cfu/g for control. The results also revealed a total of eight bacterial genera and they include; *Bacillus* sp, *Pseudomonas* sp, *E.coli*, *Microccus* sp, *Staphylococcus* sp, *Proteus* sp, *Enterobacter* sp, *Klebsiella* sp respectively. Total fungal count ranged from 1.5 ± 0.97 to $2.9 \pm 0.92 \times 10^5$ cfu/g for soil samples treated with composted waste paper. A total of five fungal genera were isolated and they included *Aspergillus* sp, *Penicillium* sp, *Mucor* sp, *Rhizopus* sp, and *Sacharomyces* sp respectively. The most prevalent bacterium across the sample was *Bacillus* sp with 33.33 % while the most prevalent fungus across the sample was *Penicillium* sp with 41.67 %.

Keywords: Bioconversion; Waste paper; Soil conditioner; Plants; Microorganisms

1. Introduction

In many countries, a large chunk of municipal waste including waste paper is not properly dispose therefore causing a potential environmental threat because of pathogens and toxic pollutants present in the waste [1, 2]. Landfill is recently not considered the best as it is problematic and leads to pollution issues such as leachate and landfill gases. Organic municipal waste and other organic materials such as waste paper and manure can be composted and used in improving soil structure and crop performance. Composting therefore is an aerobic process which enables the organic matter to decompose to humic -like substances. The quantity of the material deduces during composting and the resulting compost is very stable and rich in nutrients than the raw material and can improve soil quality and crop productivity and also sustain agricultural production [3]. The high cost of inorganic fertilizers and the potential environmental risk that results by overuse have awoken the interest in using organic matter amendments such as plant residues including waste paper, manures and composts.

However, compost properties differ greatly depending on compost materials and procedure [4]. Effective and optimal use of compost depends on a better understanding of the relationship between the properties of compost and their effect on soil. The use of waste paper as source of plant nutrients and organic matter to ameliorate soil structure is of great interest to maintain soil productiveness [5, 6] especially in low carbon input rotation systems.

Enhancement of soil structure and soil carbon content increase after application of waste paper could be dependent on the segment of their organic carbon in the varying and stable carbon pools. Their effects on aggregation of soil and accumulation rate of carbon do not only depend on the quantity but also on the quality of the organic wastes. The rate

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of the decomposition of the organic wastes by soil microbes is connected to the rates at which the organic wastes are decomposed by soil microorganisms and therefore influence their ability to stimulate the soil microflora and produce humic substances [7, 8].

Soil aggregation is a result of the product that is formed during decomposition of polysaccharides, humic substances and microbial products along with phenolic [9, 10]. Waste papers and sludge are lignin-rich organic material known to resist mineralization [11] and therefore adds to increase in the soil organic matter content [12, 8, 13]. A long-lasting effect of waste paper and sludge may be observed on soil structure [14] and fertility compared to some other animal manure which generally induce short-term improvement due to their high mineralization potential as demonstrated by Darwish et al. [15]. This study will therefore bioconvert waste paper into soil conditioner through composting and will determine the effect of the produced soil conditioner on soil microorganisms and plant growth.

2. Material and methods

2.1. Description of study area

This research study was done at the botanical garden of Akwa Ibom State Polytechnic, Ikot Osurua, Ikot Ekpene, Nigeria. The experiment was done in March 2018 and the work lasted for four months.

2.2. Sample collection and preparation

Waste paper was collected around Akwa Ibom State Polytechnic offices and paper waste bins. Maize seeds were purchased from a nearby community market at Ikot Osurua, Ikot Ekpene in Akwa Ibom State, Nigeria. The waste paper and the maize seeds were taken to the botanical garden of Akwa Ibom State Polytechnic for studies.

2.3. Waste paper composting

Waste paper was grinded using a grinder. The grinded waste paper was kept and allowed to decompose. Water was sprinkled on the compost heap at 4 days interval to aid decomposition and the temperature of the windrows and the atmosphere was taken. Microbiological analysis of the windrows was carried out at weekly intervals. The composting process was allowed for 21 days.

2.4. Microbiological analysis

Samples of the composted paper were taken at weekly intervals and analyzed for total bacterial count (TBC) and total fungi count (TFC). Serial dilution of the composted waste paper was carried out, 1 mL inoculums of a known dilution factor was inoculated in a prepared nutrient agar and sabouraud dextrose agar (SDA) for bacterial and fungal growth respectively. The prepared plates were incubated at 37 °C in the incubator for 24 hrs in the case of bacterial culture and fungal culture was incubated in room temperature for 4 to 5 days. After incubation, bacterial isolates were characterized using cultural, morphological and biochemical characterization which include Gram-stain, catalase test, methyl red test, indole test, urea test, spore stain, motility test, coagulase test and sugar fermentation test. Isolates were identified according to the method of Cheesbrough [16]. Fungal isolates were characterize and identified using their macro-morphological, microscopic examination in lacto-phenol cotton blue stain for viewing hyphae, reproductive structures, filaments, spores head etc

2.5. Determination of the effect of composted waste paper on plant growth

After the composting process had ended, the composted waste paper was weighed out into four portions of 600 g, 400 g, 200 g and 100 g respectively. 1 Kg of soil sample was added to each portion. The fifth portion was made to serve as control (1 Kg of soil not treated with the paper waste). Each treatment was filled into a polythene bag; polythene bags were perforated before filling with the treated soil samples and four seeds of maize were planted on each of the treated soil in the polythene bags. The treatments were kept in the botanical garden and were watered at three days interval.

2.6. Seed germination studies

Germination studies of the maize seeds were carried out at day 4 to determine the number of seeds that have germinated using the method of Jinadasa et al [17] and Ibuot et al [18]. Plant height was determined at 4 days interval.

2.7. Determination of plant growth

Plant growth was determined by measuring plant height with use of a meter rule and the number of leaves was counted at 4 days interval using the method of Ibuot et al [19].

3. Results and discussion

3.1. Total bacterial count of waste paper compost

Total bacterial count of composted paper waste amended soil showed high bacterial count compared to the soil not amended with composted waste paper (control) (Table 1).

Table 1 Total Bacterial count (cfu/g) of composted waste paper with soil

Sample Duration	Sample treated/ Bacterial count (x10 ⁵ CFU/g)				
	S1kg+ PW 600g	S1kg+ PW 400g	S1kg+ PW 200g	S1kg+ PW 100g	S1kg+ PW 0g
Day 1	5.9±1.23	4.0±1.01	4.7±0.98	5.0±1.09	5.0±0.78
Day 7	11.8±0.87	99.0±1.78	76.0±1.09	69.0±1.03	61.0±1.29
Day 14	13.3±1.24	11.9±1.09	11.5±1.01	11.5±1.01	11.3±1.35
Day 21	14.1± 2.01	12.5±1.01	12.3±1.07	12.3±1.10	11.5±1.07

Key: S- soil, PW – Waste paper

3.2. Bacterial percentage frequency of occurrence in soil amended with waste paper compost

Bacterial percentage frequency of soil amended with waster paper compost showed *Bacillus* sp and *Pseudomonas* sp with highest frequency of occurrence 33.33 % and 26.67 % respectively (Table 2).

Table 2 Percentage occurrence of bacterial isolates of composted waste paper with soil sample

Isolates	Sample treated				
	S1kg+ PW 600g	S1kg+ PW 400g	S1kg+ PW 200g	S1kg+ PW 100g	S1kg+ PW 0g
<i>Bacillus</i> sp	29.27	10	29.09	17.39	33.33
<i>E. coli</i>	17.07	12	8.70	26.09	6.67
<i>Klebsiella</i> sp	24.39	20	13.04	13.04	0
<i>Micrococcus</i> sp	9.76	8	17.39	4.35	20.0
<i>Proteus</i> sp	2.44	8	8.70	8.70	0
<i>Staphylococcus</i> sp	4.49	12	13.04	17.39	13.33
<i>Pseudomonas</i> sp	7.73	16	4.35	13.04	26.67
<i>Enterobacter</i> sp	4.49	4	8.70	0	0

Key: S- soil, PW – Waste paper

3.3. Total fungal count of waste paper compost

Total fungal count of composted paper waste amended soil showed high fungal count compared to the soil not amended with composted waste paper (control) (Table 3)

Table 3 Total fungal count (CFU/g) of composted waste paper with soil

Sample duration	Sample treated / fungal count (x10 ⁵ CFU/g)				
	S1kg+ PW 600g	S1kg+ PW 400g	S1kg+ PW 200g	S1kg+ PW 100g	S1kg+ PW 0g
Day 1	2.0±1.34	1.5 ±0.97	2.0±0.98	1.9±1.09	1.8±1.43
Day 7	2.3±0.98	1.7± 0.09	1.90±0.95	1.7±0.91	1.7±1.08
Day 14	2.9±0.92	2.6± 1.06	1.90±1.02	1.9±0.08	1.9±0.98
Day 21	2.6 ±1.10	2.9 ±1.03	2.7±0.78	2.2±0.09	1.8±0.19

Key: S- Soil, PW- Waste paper

3.4. Fungal percentage frequency of occurrence in soil amended with waste paper compost

Fungal percentage frequency of occurrence of soil amended with paper compost showed *Penicillium* sp with the highest frequency of occurrence of 41.67 % (Table 4).

Table 4 Percentage occurrence of fungal isolates

Isolate	S1 kg+PW600 g	S1 kg+ PW400 g	S1 kg+PW200 g	S1 kg+ PW100 g	1 kg+0 g
<i>Aspergillus</i> sp	29.17	26.32	41.18	8.33	10.0
<i>Penicillium</i> sp	16.67	21.05	11.76	41.67	30.00
<i>Mucor</i> sp	4.17	10.53	5.88	25.00	20.00
<i>Rhizopus</i> sp	8.33	0	17.65	16.67	40.00
<i>Saccharomyces</i> sp	41.67	42.11	23.53	8.33	0

Key: S- Soil, PW- Waste paper

3.5. Seed germination studies

Germination studies of seed showed 100% germination for soil amended with waste paper compost and the control (soil not amended with waste paper compost) (Table 5).

Table 5 Percentage (%) seed germination of seeds planted on soil treated with composted wastepaper

Day/ germinated seed	%	S1 kg+PW600 g	S1 kg+ PW400 g	S1 kg+PW200 g	S1 kg+ PW100 g	S1 kg+PW0
	100	100	100	100	100	100

Key: S- Soil, PW- Waste paper

3.6. Plant height

Plant height showed soil amended with composted waste paper having highest height compared to soil without composted waste paper (Table 6).

Table 6 Height of seedlings planted in waste paper composted treated soil

Isolate	Seedlings height (mm) / Days				
	Day 6	Day 10	Day 14	Day 18	Day 22
S1 kg+PW600 g	87±0.67	115±2.01	284± 2.67	475± 2.11	643±1.76
S1 kg+ PW400 g	80±0.89	121±1.88	258± 1.98	453 ± 1.70	606±0.98
S1 kg+PW200 g	83± 1.09	135±1.19	221±0.67	386 ±0.94	547±1.70
S1 kg+ PW100 g	80± 0.98	112± 1.91	220± 1.19	369 ±1.28	518±1.02
S1 kg+PW0 g	70± 1.98	170±0.95	216± 1.10	354± 1.36	503±1.67

Key: S- Soil, PW- Waste paper

4. Discussion

Compost production is considered an economic and environmentally friendly means to reduce the waste going into landfill. Compost application can improve soil quality and productiveness as well as maintaining of agricultural production by improving soil organic matter and supplying nutrients. Organic matter is a vital component of a healthy soil as it plays important role in soil physical, chemical and biological fertility. On the contrary, compost application can also exert some adverse effect on the soil fertility as well as microbial population thus, the aim of the present study.

In the present study, the results obtained revealed that waste paper had some effect on the soil fertility and microbial population as well compared to soil not amended with waste paper compost. The effect exerted by this composted waste paper was seen to change overtime with respect to the concentration of the waste paper in an environment. The results showed that seed were able to germinate 100 % on both soils amended with composted waste paper and the control (soil not amended with composted waste paper). The germination of the seeds on day four [4] indicates the metabolic process exerted by some organisms through the secretion of enzymes to decomposed the waste to produced requirement necessary for growth [3]

The results obtained from microbiological assessment revealed a total of eight bacterial genera which include *Bacillus* sp, *E. coli*, *Klebsiella* sp, *Micrococcus* sp, *Proteus* sp, *Staphylococcus* sp, *Pseudomonas* sp and *Enterobacter* sp while a total six fungal genera were isolated which were; *Aspergillus* sp, *Penicillium* sp, *Mucor* sp, *Rhizopus* sp and *Saccharomyces* sp . The results obtained agree with the work of who reported Okoh et al., [20] that compost genera increase the abundance of soil microorganisms. The predominant occurrence of *Bacillus* sp across the sample also agrees with the work of Bossio et al [21] who reported that addition of compost from various sources has been shown to increase the abundance of gram positive bacteria. The presence of *Staphylococcus* sp was not a surprise as though this is not a bacterium found in the soil could be associated with the waste paper as a result of contact with human hands. *Micrococcus* sp and *Pseudomonas* sp have been reported as soil bacteria [18, 19, 22, 23]. The results obtained also showed that the presence of these pathogens in the soil could in turn affect the soil fertility by reducing plant nutrient uptake which in turn will affect plant growth. The increase in the microbial population with time agrees with the work of Lozana et al., [24] who reported that changes in microbial activity and community structure after compost application can lead to the increased of soil –borne plant pathogens. The presence of these fungal isolates in the soil samples was not a surprise as there are all soil fungi [25].

The result of the germination study of seeds planted in soil treated with composted waste paper showed 100% germination for all seeds planted in the different soils treated with the sample which agrees with the work of Lin et al., [26].

The plant, *Zea mays* showed high growth in soils amended with composted waste paper as determined by plant heights and number of leaves compared to the one planted in soil not amended with composted waste paper. Soils amended with organic matter generally have shown to contribute to carbon accumulation and a subsequent improvement of soil fertility and structure, as reported by Darwish et al. [15] and Varvel [27]. The presence of organic manure in the soil is reported to have positive effects on the soil parameters. Sanchez et al., [4] reported that the presence of organic matter in the soil increases soil pH. It is also reported that it replenishes the soil with essential elements and add humus to the soil. This gives enabling environment for increase in microbial growth and plant performance [28].

5. Conclusion

Waste paper management is a major challenge in densely populated areas like educational institutions, secretariats, hospitals etc. In most cases waste papers are disposed into gutters where they cause blockage and water flood during rainy season. Disposal of waste paper with other waste would lead resources waste that could be converted and reused as soil conditioners. In this study, soil amended with composted waste paper has shown to improve plant growth and performance. This clearly shows that waste paper could be composted and used as soil conditioner.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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