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EFFECT OF ORGANIC MULCHES ON SOIL PRODUCTIVITY AND MICROBIAL ACTIVITIES IN ACID SANDS OF UYO, NIGERIA

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ABSTRACT
A study was conducted to assess the effects of three mulching materials; Chromoalaenaodorota(CH), Elusineindica (EI) and Saw dust (SD) on soil properties and microbial activity in acid sands of Uyo ,Nigeria. The trial was laid out in a completely randomized design with three replications between April, 2012 and October, 2013. The experimental plot measured 96m² was cleared manually and the three mulching materials chopped into pieces, cured before each worked into each experimental plot at the rate of 10t/ha with minimum tillage. Soil samples were collected at 6 and 12 weeks after mulch application for determination of soil properties and 2, 4, 6, 8 and 10 weeks after mulch applications for determination of microbial populations. Results revealed that the three mulching materials increased physical, chemical and biological properties of the soil. Effect of the mulching material son nitrogen, phosphorous organic carbon and basic captions (Na^+ K^+ Mg^{2+} and Ca^{2+}) were however highly dependent on their C:N ratios. Mulching with CH and EI with low C:N rates of 13:1 and 17:1 significantly increased the soil properties and biological activities and reduced soil bulk density in all the treatments. On the other hand, mulching with saw dust with high C:N ratio of 20.75:1 stimulated microbial growth and added little nitrogen to the soil. Microbes immobilized a high proportion of the limited nitrogen pool. This study demonstrates that organic mulches can have major effect on soil fertility and that.
Keywords: *Microbial activity, Acid sands Organic molecules, soil productivity*

INTRODUCTION
Mulching is a crop husbandry practice in which organic or inorganic materials are spread over the soil surface to influence the physical, chemical and biological properties of the soil and its micro-climate with the aim of improving the productivity of the soil (Muller-Samamn and Kotschi, 1994). Mulching is also an inexpensive strategy of reducing soil erosion by first, protecting the soil from the impact of rain drops energy by ensuring that soil pores remain open to take in rain water. Secondly, it slows down the run off speed of water thereby preventing it from carrying too much soil (Lal, 1975) and thus contributes to maintenance of good soil structure (Sandchez and Salinas, 1981). The effects of mulch on soil structure are not only the protection it's afforded from sun and rain, but also of the increased biological activity that develops beneath the mulch cover (Lal, 1978). Soil microbes act both as a source and sink of available N through opposing processes of mineralization and immobilization (Sequestration of inorganic N in microbial biomass), and subsequent demineralization of nitrogen as soil microbes get

decomposed (Keeney, 1980). The balance between nitrogen mineralization and immobilization is strongly influenced by the C:N ratio of the decomposing organic matter (Facelli and Pickett, 1991; Kaye and Hart, 1997). Organic matter with a C:N ratio greater than 30:1 does not contain enough nitrogen to support microbial growth (Kaye and Hart, 1997), and microbes must scavenge additional nitrogen from the soil The fact that soil microbes are considered stronger competitors for nutrients than plants implies that much of the available nitrogen pool will be immobilized by soil microbes and be unavailable to plants (Wang and Bekken, 1997). Conversely, decomposition of organic matter with a C:N ratio less than 30:1 increases nitrogen availability for plants because nitrogen is mineralized in excess of microbial requirements (Kaye and Hart, 1997). Due to skyrocketing prices of mineral fertilizers beyond the reach of rural farmers, the need to source for alternative fertilizer is inevitable. Therefore the objectives of this study were to investigate the effect of mulches on soil properties and microbial activities in the Acid Sands of Uyo, Nigeria.

MATERIALS AND METHODS

The study was conducted from2012 to 2013 at the University of Uyo Teaching and Research Fam. Uyo lies between latitude 5.17° and 5.27° N and longitude 7.27° and 7.58° E. The area is characterized by two distinct seasons, wet and the dry seasons. The wet season starts from March to October, while the dry season starts from November. A short dry spell is normally noticed in August and is traditionally referred to as August Break. The rainfall ranges from 2000-3000mm; the temperature is uniformly high and ranged from 28-30°C. The soils of Uyo are formed from coastal plain sands parent materials and is described as Acid Sands (Arenichaphidult) because they are generally sandy and acidic with pH ranging from 4.0-6.0 (Kang *et al.*, 1996).

Field Study: The plot measured 16x6m (96m^2) and was cleared manually using machete and hoes and laid out in a completely randomized design with three replications, each replicate was divided into 3 experimental units with each measuring 0.6 x 6m and separated from the other by apath of 0.3m. Three mulching materials: *Chromolaenaodorota,* (CH), *Eleusineindica*(El), and saw dust (SD) were used. *Chromolenaodorota* and *Eleusineindica* were chopped into pieces with machete cured before application at the rate of 10t/ha. Minimum tillage was carried out on the experimental units before the application of the mulching materials.

Soil sampling and analysis:-Composite soil samples were collected before application of mulching materials at the depth 0-15 and 15-30cm to serve as control.

Other soil samples were collected at 6th and 12th weeks after applications of mulching material from each of the experimental plot. In microbiological study, soil samples were collected at 2, 4, 6, 8 and 10th weeks after mulch application. The samples were transported in well labeled polythene bags to the laboratory. In the laboratory the soil samples were air-dried, crushed with pestle and mortar and then sieved through 2mm mesh sieve, stored for physical and chemical analysis. Soil analysis was carried out using standard laboratory procedures as outlined by Udo*et al.* (2009). Soil pH was determined in a 1:2.5 (soil/water ratio) and the result read by using a digital pH-meter (model no PHS-3C) the organic matter content was determined by using dichromate-oxidation method (Udo*et al.*, 2009), total nitrogen wasdetermined by micro-Kjeldahl apparatus (Jackson, 1962). Available phosphorus was extracted using Bray P-1 extractant (Bray and Kurtz, 1945) and read on Spectrophotometer(of Bean De Rondo BV-Cam Spec). Exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+} and Na^{2+}) were extracted using 1N Ammonium acetate at pH 7.0, Na and K were determined on flame photometer while Ca and Mg were determined using the EDTA filtration method (Jackson, 1962). Bulk density (gcm^3) was calculated as the ratio of weight of oven dried soil to the volume of soil (cm^3) contained in the core samples (Klute, 1986).

Analysis of Mulching Materials: The leaves of *Eleusineindica, Chromolaenaodorota* and 50g of saw dust were oven dried at 65°C for 48 hours. The samples were ground using electric blender and stored in labeled clean bottles for chemical composition analysis (IITA, 1989).

Table 1: Chemical Composition of the Mulching Materials

	N	Ca	Mg	Na	K	P
SD	3.10±0.3	6.8±1.2	1.59±0.5	2.20±0.1	4.58	350
CH	26±4.2	2.86±0.5	7.5±1.2	1.70±0.02	315	3.0
EI	18.0±2.6	15.6±3.1	4.62±1.0	2.9±0.15	1.50	1.6

SD =Saw Dust, CH - Chromolaenaodorota, EI –Elucineindica

Microbial Isolation Methods: The serial dilution technique was used for soil plate counts. Heterotrophic bacteria were estimated using Nutrient agar (oxoid)as growth medium containing 1.0g lemco powder, 2.0g yeast extract, 5.0 peptone, 5.0 NaCL, 15g agar, 1000ml distilled water, while heterotrophic fungi were estimated with Potato dextrose agar (oxoid), with the following composition, 4.0g Potato extract, 20g dextrose, 15g agar, 100ml distilled water (Allen 1959). Equal volumes of 1ml of every soil dilution were inoculated on respective nutrient culture medium. Bacterial plates were incubated at 37°C for 24hrs while fungal plates were incubated at room temperature (28°C) for 72 hours. At the end of each incubation period, visible discrete

colonies in incubated plates were counted and expressed as colony forming units per gram soil (Cfu/g)

RESULTS AND DISCUSSION

Mulching with *chromolaenaodorota* (CH), *Elucineindica* (EI) and sawdust (SD) had positive effects on soil properties after 6 and 12 weeks of application (Tables 2 and 3). After 6 weeks of mulch application, there was increased in soil pH, and a shift from extremely acid condition in the unmulch (control) plot with the pH 4.36 to moderately acid in soil mulched with CH and EI with pH value of 5.02 and 5.60, respectively. The soil treated with sawdust was extremely acid with a pH of 4.43. The increase in the pH of the three mulched plot were 8.07%, 6.20% and 2.07%,respectively for the CH, EI and SD plots relative to the control. The increase in the soil pH may be attributed to the activities of earthworms that excrete their casts on the soil surface which played an important role in restoring calcium that led to the increase in the soil pH. A general increase in organic carbon content of the soil was observed in all the mulched plots relative to the control. Soil mulched with CH, had 1.74% organic C which was 8.07% higher than the control with 1.61%organic C. On the other hand, the plot mulched with EI had organic C of 0.71 $\pm$ 0.02% higher than the control which is 6.21%.Total nitrogen was also observed to have increased following the application of the mulches. The effect organic matter and microbial activities had on nitrogen availability, however, were highly dependent on the C:N ratio of the mulching materials. *Chromolaenaodorota,* and *Elucineindica* had low C:N of 10.88:1 and 12.14:1 respectively, which significantly ($P<0.05$) increased soil total nitrogen at 6 weeks after mulch application (Table 2) at the rates of 166 and 133%, while the plot mulched with sawdust with the C:N ratio of20.75:1 increased the soil total nitrogen by 33% at 6 weeks after mulched application. At 12 weeks after mulch application, further increase in soil pH was observed in all the treatments. The plots mulched with *Chromolaenaodorota, Elucineindica* and sawdust increased soil pH by 26%, 15.24% and 10.53%, respectively.

Table 2: Soil Properties of the Treatments at6 weeks after mulching

Parameters Studied	NM (Control)	CH	EI	SD
pH	4.34±1.2	5.02±0.5	5.60±0.4	4.43±1.2
Org. Carbon (%)	1.61±0.20	1.74±0.02	1.71±0.02	1.66±0.4
Total N (%)	0.06±0.02	0.16±0.01	0.14±0.04	0.08±0.0
C;N	26.83±4.1	10.88±2.5	12.14±3.0	20.75±4.2
Av.P(mg/kg)	60.41±5.2	68.63±5.3	65.65±4.2	58.43±5.3
Ca^{2+}	2.50±0.5	2.60±0.0	2.60±0.1	2.52±0.2
Mg^{2+}	1.20±0.02	1.58±0.6	1.52±0.03	1.52±0.3

$Na^{+(Cmol/kg)}$	0.10±0.0	1.14±0.2	0.17±0.0	0.12±0.0
K^{+}	0.03±0.0	0.05±0.0	0.07±0.0	0.03±0.0
EA	2.41±0.2	1.53±0.3	2.53±0.21	2.63±0.3
ECEC	6.31±2.1	6.87±2.1	6.87±2.1	68.2±5.4
Base Saturation(%)	61.00±5.1	63.61±5.3	63.28±5.3	61.43±5.1
BD (g/cm^3)	1.25±0.01	1.14±0.5	1.15±0.03	1.15±0.2

NM = No Mulch (Controls), EI = (Elucineindica)
CH = Chromolaenaodorrota, SD = Saw dust

Organic carbon increased from 1.62±0.2% at6 weeksafter mulch application to 1.77±0.6, 1.75±0.02 and 1.63+0.2%at 12 weeks after mulch application for the soil treated with *Chromolaenaodorota, Elucineindica* and sawdust, respectively. Organic C increased from 1.62±0.2% in the control to 1.77±0.6, 1.75±0.25 and 1.63±0.2% respectively for the plots mulched with *Chromolaenaodorota, Elucineindica* and sawdust at 12 weeks after treatment. The rates of increase were 9.25, 8.02 and 0.61% for plot mulched with *Chromolaena, Elucineindica* and sawdust, respectively (Table 3). The increase may be due to the mineralization of organic matter applied. Total soil nitrogen significantly ($P<0.05$) increased at 12 weeks after mulch application relative to the control in the plot mulched with *Chromolaena, Elucineindica* and sawdust, respectively. The treatment effects were profound on soil nutrients status as measured in terms of organic carbon and total nitrogen over the unmulched control plot. Mulched plots using *Chromolaena* and *Elucineindica* produced significant ($P<0.05$) increase in total nitrogen and organic carbon over the plot treated with sawdust. The magnitude of organic carbon and total nitrogen increase could be due to increased microbial activity and the qualities of the mulched materials are measured in terms of C: N ratio. These results corroborate with the report by Hena *et al.* (1999) who reported that the addition of organic wastes with low C: N ratio increased biomass C in the soil. Paul and Mannan (2006) also obtained increased microbial C and N formation through addition of straw of high C: N ratio. The efficiency of nutrient recycling from applied mulch is predicated on activity of soil microbial population of applied materials. AvailableP increased from 60.41±5.2mg/kg soil in the unmulched control plot to 68.62±5.3, 65.66±4.2 and 58.48±3.3 in plots mulched with *Chromolaena, Elucineindica* and sawdust, respectively at 6 weeks after mulch application. Similarly, at12 weeks after mulch application, available phosphorus increased from 60.42±5.0 in the control to 70.03±6.0, 66.50±2.5 and 60.42mg/kg in the soil mulched with *Chromolaena, Elucineindica* and sawdust respectively. The plots mulched with Chromolaena and *Elucineindica* had available Psignificantly ($P<0.01$) higher than the control plot, while there was no significant different in available P between the unmulched and the plot mulched with saw dust. The increase in available Pmay is attributed to the

mineralization of the high content organic P in the organic matter added to the soil, by the activity of microorganisms. Basic cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) increased significantly ($P<0.05$) in all the mulched plots relative to the control (unmulched) plots at 6 and 12 weeks after mulch application. The increase in the basic cations may be due to the quality and profound effect of applied mulch materials had on soil biogeochemical properties which may be related to contents of organic carbon and nitrogen (potentially mineralizable N) in the materials applied. Soil fertility enhancement by mulch obtained can also be attributed to the promotion of microbial activity and consequent decomposition of the applied materials. The results corroborate earlier study by Okigbo (1980) who reported that significant amounts of nutrients are added or returned to the soil with crop residues and especially with mulch brought to the field from elsewhere.

There was a reduction in bulk density of the soil from 1.25gcm^3 in the control to1.14±0.05, 1.15±0.03 and 1.15±0.03gcm^3 in the plots mulched with *Chromolaena,odorota, Elucineindica* and sawdust respectively at 6 and 12 weeks after mulch application, bulk density reduced from 1.22±0.03g/cm^3 in the control to 1.20±0.2, 1.20±0.2 and 1.21±0.6g/cm^3 in plots mulched with *Chromolaenodorota, Elucineindica* and saw dust, respectively. The reduction in the soil bulk density in the mulched plots may be due to the activities of both macroorganisms (e.g. earthworm) and microorganisms acting as pulverizers to the soil predicated by the addition of organic materials to the soil. The soil fertility (nutrients) enhancement by mulch obtained can be attributed to the promotion of microbial activity and consequent materials. Soil organic matter is a key factor in maintaining long-term soil fertility. The plot mulched with sawdust which had high C:N ratio of 20.33:1+5.0 did not contribute significantly to N content of the soil and other nutrients. The saw dust mulch stimulated microbial growth without adding significant nutrients to the soil. This may be because microbes assimilated most of the existing soil nutrients to support their growth, thereby limiting the amount of nutrients available to the soil for plant growth (Wang and Bulken, 1997).

Table 3: Properties of Soils of the Experimental Site at 12 Weeks after Mulching.

Parameters	NM	CH	GR	SD
pH	4.46±0.5	5.62±1.2	5.14±2.0	4.93±1.5
Org. Carbon %	1.62±0.2	1.77±0.6	1.75±0.2	1.63±0.2
Total N %	0.06±0.01	0.26±0.05	0.25±0.03	0.08±0.02
C/N	27.00±3.1	7.69±1.5	7.64±2.0	20.33±5.0
AV.P mg/kg	60.42±5.0	70.03±6.0	66.50±2.5	60.42±7.0
Ca^{2+}	2.50±0.3	2.65±0.1	2.63±0.6	2.62±0.2
Mg^{2+}	1.59±0.1	1.68±0.3	1.62±0.5	1.82±0.35
Na^{+} Cmol/kg	0.08±0.02	0.16±0.01	0.18±0.01	0.14±0.01

K^+	0.02±0.0	0.08±0.001	0.17±0.02	0.46±0.03
EA	2.41±0.1	2.53±0.5	2.50±0.5	2.63±0.4
ECEC	6.60±1.2	7.05±2.5	7.10±2.0	7.67±1.5
B.S %	63.59±6.1	64.21±5.0	64.78±5.2	63.67±7.01
BD (g/cm^3)	1.22±0.03	1.20±0.6	1.20±0.2	1.21±0.6

NM = No Mulch (Controls), El = Elucineindica
CH = Chromolaenaodorrota, SD = Saw dust

Effects of Mulches on Microbial Populations in the Soil

The microbial counts of microorganism isolated from each mulched plot are shown in Figures 1 and 2. Total heterotrophic bacterial counts (THBC) ranged from 11.00(±2.0)x10^{6}cfu/g in the unmulched control soil to 12.50(±205)x10^{6}cfu/g, 13.20(±3.0) and 11.10 (±2.0)x10^{6}cfu/g in the plot mulched with *Chromolaenaodorota, Elucineindica* and saw dust, respectively at 12 weeks after mulch application, while depression was observed in the population of heterotrophic bacteria. The decline in the total heterotrophic bacterial counts these periods may be due to the activity of some bacterial species that flourish significantly when readily available organic nutrients are added then decline once their nutrient source is depleted. After the depletion, the total heterotrophic bacterial counts was noticed to rise at 6 weeks after mulch application from 11.60 (±2.1)x10^{6}cfu/g in unmulched control plot to 14.10±3.5, 12.30+2.1, 13.60(±3.1)x10^6 cfu/g for plots mulched with CH, El and SD, respectively. In week 8, total heterotrophic bacterial counts increased from 12.30(±3.5)cfu/g in the unmulched(control) plot to 15.40 (±3.2)x10^6) cfu/g, 16.00(+4.2)x10^6 cfu/g and 14.50 (±3.5x10^{6}cfu/g for plots mulched with CH, El and SD, respectively. In week 10 after mulch application, the total heterotrophic bacterial counts increased from 12.80(±2.2)x10^{6}cfu/g in the control plot to 17.10(±5.0)x10^{6}cfu/g, 19.30(±2.2)x10^{6}cfu/g and 17.70 (±5.0)x10^{6}cfu/g in the plots mulched with CH, El and SD ,respectively. The increase noticed from the 6thweeksaftermulch application may be due to

The succession of previous bacterial species specialized in degrading less resistant parts of the organic matter applied by these specialized in degrading more resistant materials such as cellulose. This observation is consistent with earlier report by Graft and Makechin (1979) on the activity and importance of soil organism with regards to energy and nutrient dynamics of ecosystem.

Fig. 1: Effect of different mulching materials on soil fungal population.

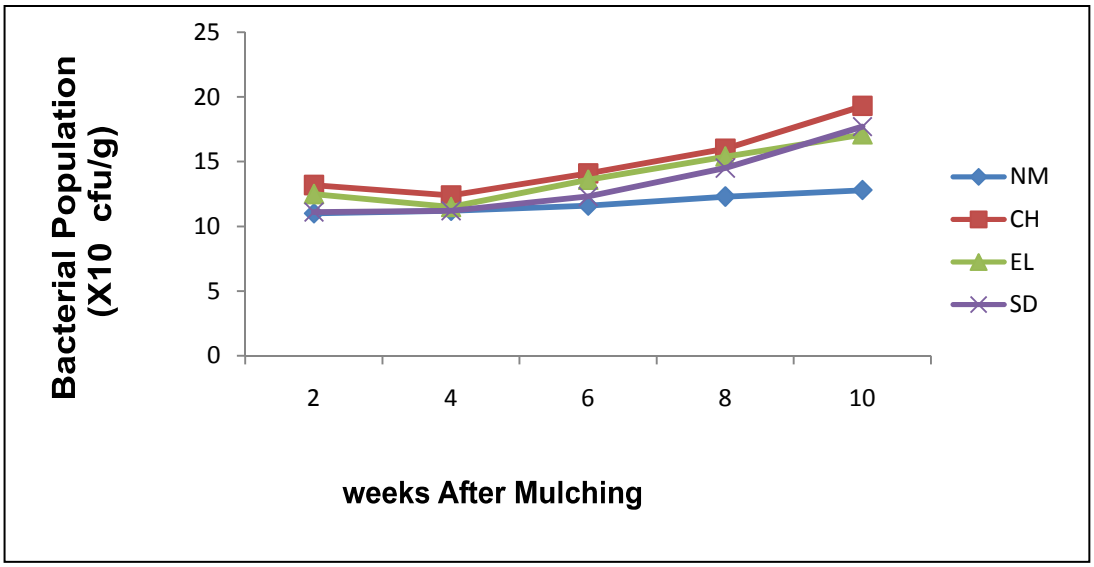

Fig. 2: Effect of different mulching materials on soil fungal population.

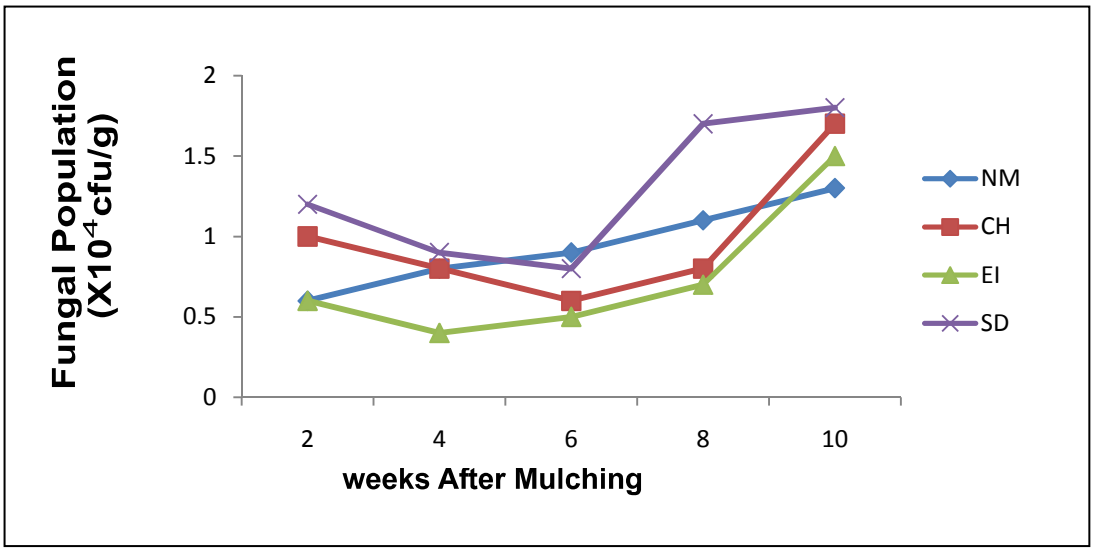

Figure 2 shows that heterotrophic fungal counts increased from 0.60 ($\pm$0.1)x10^{6}cfu/g soil in the control to 1.60 ($\pm$0.21)x10^6, 1.00 ($\pm$0.2)x10^6 and 1.20 ($\pm$0.21)x10^{6}cfu/g in the plots mulched with CH, EI and SD, respectively at 2 weeks after mulch application. Depression was observed in fungal population between weeks 4 and 6 after mulch application and thereafter increased in Wks8 and 10 after mulch application. The rise in fungal population is because application of any organic matter to the soil may lead

to increase background levels of microbial activities, increase nutrients cycling, decrease concentrations of easily available nutrients sources and increased microbial diversities. Also, fungal population increased in weeks 8 and 10 after mulch application and might be due to their inability to compete successfully with bacteria in the early stage of nutrient addition or their ability to synthesize enzymes involved in cellulose and lignin degradation. This finding is inconsistent with the report of Alexander (1976) that decrease in fungal population during initial application of organic matter may be due to the vigorous multiplication of bacteria which may results in depression of fungal population. on the other hand (Pandidas (1973) suggested that subsequent increase in fungal population may be due to fungal ability to degrade liter with more recalcitrant carbon sources such as with high cellulose and lignin contents.

CONCLUSION

This study has demonstrated that the three mulching materials *Chromolaenaadorota, Elucineindica* and saw dust increased soil chemical and biological properties. *Chromolaenaodorota* and *Elucineindica* with low C:N ratio significantly increased soil organic carbon, total nitrogen ,available phosphorous and basic cations and decreased in soil bulk density. Biological properties of the soil was also increased, Therefore, the organic mulches can serve as alternative sources of fertilizer for crop production.

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