Effect of mulch materials on soil physico-chemical properties and the performance of castor bean plant (*Ricinus communis*) in rivers state, Nigeria

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**ABSTRACT**

Mulches are known to conserve soil moisture, provide organic matter, protect soil and improve the soil as a growing environment. A field experiment was conducted to assess the effect of various mulch materials *viz.* dry oil palm bunch, saw dust and dry elephant grass at 25, 50 and 25 tons ha\(^{-1}\), respectively along with black plastic mulch on some soil physical and chemical properties and the performance of castor bean plant (*Ricinus communis*). All the mulches were applied to a mulch thickness of 5cm in this study. Results showed that pH values, organic carbon content and total nitrogen were all significantly improved by mulching. Bulk density values were reduced to 1.10 - 1.18 g cm\(^{-3}\) across all treatments, when compared to the control at 1.33 g cm\(^{-3}\). At 6 WAP, plastic mulching increased number of leaves from 16 to 40 leaves per plant and capsule weight from 63.1 to 161.3g/plant; when compared with the control.

**Key words:** Castor bean performance, Mulching, Soil properties.

**INTRODUCTION**

The castor bean plant (*Ricinus communis*) is a specie of flowering plants in the spurge family: Euphorbiaceae (Weiss, 2000). Castor is indigenous to the southeastern Mediterranean basin, east African and India (Mercola, 2012), but it is widespread throughout the tropical region and basically grown for its industrial and medicinal use (Lampe and McCann, 1985, Cooper, 1989).

Castor bean seed is the source of castor oil which is a vegetable oil obtained by pressing the seeds of the castor oil plant (Alfred, 2015). Castor oil and its derivatives are used in the manufacturing of cosmetics, pharmaceuticals and perfumes (Mutlu and Meier, 2010). The united states food and drug administration (FDA) has categorized castor oil as “generally recognized as safe and effective” for over-the-counter use as laxative with its major site of action the small intestine, where it is digested into ricinoleic acid (Castor Oil a and b).

European union countries were the main importers of castor oil. Their importation increased by 18.15% in the period 2003 to 2010 (FAOSTAT, 2010). China increased castor oil imports by 59%. It has also been reported that mulching significantly increased the performance of castor bean plant in Asia (Silva *et al.* 2014).

This high yielding and short duration crop with its wide range of uses and global demand as cash crop, makes it a crop to be desired. Its cultivation and domestication in the Niger Delta Region of Nigeria has received little or no attention.

The present study, therefore is aimed at assessing its performance and yield with various mulch materials in the dry season and also its effect on the physical and chemical properties of the soil.

**MATERIALS AND METHODS**

The experiment was conducted at the teaching and research farm of the Rivers State University of Science and Technology, Port Harcourt, with a mean annual rainfall ranging between 3000 and 4000mm (Okonkwo, 2010) and average annual temperature of about 23°C.

The Zibo Castor No5; a middle maturing hybrid variety bred by Zibo Academy of Agricultural Sciences (Chinese Hybrid Castor), was used. The mulching materials used included dry oil palm refuse, saw dust, dry grass and black plastic mulch. The dry oil palm bunch from an oil palm processing mill and saw dust from a saw mill in Obrikom Rivers State, Nigeria. Dry elephant grass (*Pennisetum purpureum*) was collected from the experimental site, while the black plastic mulching material was purchased from a local market in Port Harcourt.

The treatments consisted of 25 tons ha\(^{-1}\) of dry oil palm bunch, 50 tons ha\(^{-2}\) of saw dust and 25 tons ha\(^{-2}\) of dry elephant grass; to a mulch thickness of 5cm. There was also a plastic mulching placed to cover the plots completely and held to the ground with soil and pegs. The control had no mulching. These six treatments, replicated thrice were laid out in a randomized complete block design. The plots were manually cleared and ridged before the various mulches were placed.

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The castor bean seeds were planted one seed per hole at a depth of 3cm, at a spacing of 1m x 1m within and between rows; giving a total plant population of 5,000 seeds per hectare. Between ridges was 2m spacing. Missing stands were supplied at 2 weeks after planting (WAP). Each plot was kept weed-free by hoe weeding or handpicking with minimal disturbance to the top soil, at 3 and 6WAP. To supplement nutrient status NPK 20:10:10 was applied to plots at 2WAP at the rate of 120 kg ha$^{-1}$ using the band placement method at a 20cm radius from the plant.

Undisturbed soil samples were collected with core samplers of 5cm internal diameter and 5cm height, as was used to analyze for bulk density, total porosity and moisture content. Bulk density was determined, using the method described by Blake and Hartage (1986). Total porosity was calculated from bulk density and an assumed average particle density of 2.65g cm$^{-3}$ using the equation:

$$P = 1 - \left(\frac{l b}{l s}\right)$$

where $l b$ is bulk density, $l s$ is particle density and $P$ is total porosity.

Gravimetric moisture content of the soils at field capacity was determined as a ratio of the mass of moisture to mass of dry soil, as described by DeAngelis (2007). The associated bulk density for each sample was used to convert the result to a volume basis with the equation:

$$\theta = (0m x l s) / l w$$

where $\theta$ is volumetric moisture content, $0m$ is gravimetric moisture content and $l w$ is density of water.

Composite soil samples were collected from the experimental site before treatment application and from the various treatments after harvest, using a soil auger at the 0-15cm depth. These samples were air dried, sieved to pass through a 2mm mesh size sieve and were analyzed routinely as described by Page et al. (1982). Soil pH (1:2.5 H$_2$O) was determined using digital electronic pH meter, total nitrogen by the micro kjeldahl approach, organic carbon by the Walkley and Black and Particle size distribution was determined using the Bouyoucos hydrometer method as described by Gee and Bauder, (1986).

The following growth and yield parameters were measured: percentage germination, plant height, number of leaves, leaf area and yield (number and weight of capsules). Data collected were subjected to analysis of variance for a randomized complete block design and means were separated using the Least Significant Difference. Where applicable, means and standard deviation from the mean were also used to analyze data collected.

RESULTS AND DISCUSSIONS
1. Effect of mulching on soil properties
a) Physical properties: properties of the test soil before treatment application is as shown on Table 1. The sandy loam soil is acidic and low in organic matter content. These conditions are typical of the Ultisols of Southern Nigeria (Lal, 1986).

Mulching improved soil physical properties (Table 2). Land preparation before planting may have caused a loosening effect which resulted in lower bulk density of the unmulched plot from 1.33 to 1.22g cm$^{-3}$, Ogbo and Nnabude, 2012a, Ojeniyi et al. (2015) reported a similar observation.

Results showed that mulching with sawdust and grass better improved the bulk density and total porosity of the soil (1.00g cm$^{-3}$ and 1.10g cm$^{-3}$ and 64% and 59% respectively) when compared with the unmulched plots (1.22g cm$^{-3}$ and 54% respectively). This may be due to their nature of material being easily degradable to organic matter, when compared with the palm bunch. Lalitha et al., (2010) also reported that mulching did not cause compaction but improved aggregate stability.

The volumetric moisture content at field capacity ranged between 0.16 to 0.31 cm$^3$ cm$^{-3}$ with the highest values for sawdust mulched plot and 0.16, for grass mulched plot. Saw dust seemed to absorb and retain more moisture than the other mulched materials.

b) Soil chemical properties: Soil pH values were improved from acidity towards alkalinity (Table 3). pH values between 6.45 to 7.00 for mulched plots, when compared to the unmulched plot with a pH value off 5.65, this indicates a neutralization of acidity with the mulching material effect. Ogbo and Nnabude (2012b) and Bhardwaj (2013) reported neutralizing of soil acidity with similar materials.

Total nitrogen was generally improved with mulching. Grass-mulched plots recorded 0.65% total nitrogen which about 100% increase in nitrogen content when compared with the other treatments.

The organic mulching materials, which excludes the plastic mulching, generally enhanced organic matter content. This agrees with reports of FAO (1993). The percentage organic matter content of the unmulched plots being higher

<table>
<thead>
<tr>
<th>Table 1: Properties of the soil of the experimental site before treatment application.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Property</strong></td>
</tr>
<tr>
<td>Bulk Density (g cm$^{-3}$)</td>
</tr>
<tr>
<td>Total Porosity (%)</td>
</tr>
<tr>
<td>Volumetric Moisture Content (cm$^3$ cm$^{-3}$)</td>
</tr>
<tr>
<td>pH (H$_2$O)</td>
</tr>
<tr>
<td>Total Nitrogen (%)</td>
</tr>
<tr>
<td>Organic Carbon (%)</td>
</tr>
<tr>
<td>Organic matter (%)</td>
</tr>
<tr>
<td>% Sand</td>
</tr>
<tr>
<td>% Silt</td>
</tr>
<tr>
<td>% Clay</td>
</tr>
<tr>
<td>Texture</td>
</tr>
</tbody>
</table>
than that of plastic mulch may be as a result of abiotic nitrogen fixation, which the plastic mulching precluded from plots mulched with it. The carbon:nitrogen ratio (C:N) was generally low, with the sawdust mulched plots having the highest value of 4.14, this still falls within the C:N ratio that allows nitrogen to be readily available to plants (Swangjang, 2015).

2. Effect of mulching on the growth and yield of castor bean
   a) Percentage germination: Percentage germination of castor bean as affected by mulching is as shown on Fig 1. Germination was generally between 6 to 10 days. This is much faster when compared with 10 to 21 days reported for unimproved varieties of castor bean (Oplinger et al. 1990) and 10 to 15 days reported for mulched cultivation (Silva et al. 2014). Across all treatments, maximum germination percentage was 70% at 10 days. Mulching positively significantly affected germination percentage, when compared with the control (Fig. 1). Lalitha, et. al., (2010) and Sharma and Bhardwaj 2017 reported that mulching positively influenced crop emergence.

   b) Plant height: Plant heights at 6WAP were not significantly different (Fig 2). However, mulching with palm bunch gave the highest mean height of 23.36cm per plant and followed by saw dust mulched plots (22.6cm). At 8WAP, the plant height of sawdust mulched plants significantly differed from all the other treatments at P < 0.05. The plant heights were in the order 65.7 > 47.0 > 38.0 > 34.7 > 33.3 cm for Saw dust > No mulch > Grass > Plastic mulch > Palm bunch, respectively. Philips and Rix (1999) reported a 2 to 3 m in a year.

   c) Number of leaves: The effect of treatment on number of leaves at 4WAP were not different (Fig 3). However, at 6WAP the number of leaves of plastic mulched plots was significantly different from the other treatments. Generally, treatments with higher plant heights had lower number of leaves, when compared with other treatments. Plastic mulched plants had mean of 40 leaves per plant while the other treatments had 10 to 16 number of leaves.

d) Leaf Area: The effect of various mulch materials on the leaf area of castor plant shows that the leaf area of castor plant (Zibo castor No 5) is between 230 and 400 cm² (Fig 4). The larger leaves were recorded for the treatment with plastic and grass mulch with 366.7 and 436.7cm², respectively. They were significantly different from the other treatments; which were in the order sawdust (300.00cm²) > No mulch (256.7cm²) and palm bunch (212.7cm²).

e) Number and weight of capsules: The number and weight of capsules as affected by mulching are as shown on Fig 5 and 6. There were no significant differences in the number of capsules per plant with mulching. However, plots mulched with sawdust and plastic mulch had 26 and 29 capsules per plant respectively, when compared with 18 capsules per plant for the unmulched plot. Plastic mulching has been reported to be conducive for castor root growth, in addition to enhancing soil properties (Castor China.com).

Physiologically, castor bean seeds are light in weight. Results of this experiments showed that there was significant difference in weight of capsules per plant at P<0.05 between the sawdust mulched plots and the other treatments, excluding the plastic mulched plots. The sawdust mulched plots had a mean (first harvest) capsule weight of 84.7g per plant which is equivalent to 423.5kg ha⁻¹; when compare with unmulched plot with 36.8g per plant equivalent to 184 kg ha⁻¹. Plastic and grass mulching had 161.3g per

### Table 2: Soil physical properties as affected by mulching at harvest of castor bean.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Bulk Density (gcm⁻³)</th>
<th>Total Porosity (%)</th>
<th>Moisture Content (cm³/g)</th>
<th>% sand</th>
<th>% silt</th>
<th>% clay</th>
<th>Textural Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palm bunch</td>
<td>1.18</td>
<td>56</td>
<td>0.21</td>
<td>77.3</td>
<td>4.0</td>
<td>18.7</td>
<td>Sandy Loam</td>
</tr>
<tr>
<td>Saw dust</td>
<td>1.00</td>
<td>64</td>
<td>0.31</td>
<td>74.9</td>
<td>4.0</td>
<td>21.1</td>
<td>Sandy Loam</td>
</tr>
<tr>
<td>Grass</td>
<td>1.10</td>
<td>59</td>
<td>0.19</td>
<td>77.3</td>
<td>4.0</td>
<td>21.1</td>
<td>Sandy Loam</td>
</tr>
<tr>
<td>Plastic mulch</td>
<td>1.15</td>
<td>57</td>
<td>0.16</td>
<td>77.3</td>
<td>4.0</td>
<td>21.1</td>
<td>Sandy Loam</td>
</tr>
<tr>
<td>No mulch</td>
<td>1.22</td>
<td>54</td>
<td>0.23</td>
<td>74.9</td>
<td>4.0</td>
<td>21.1</td>
<td>Sandy Loam</td>
</tr>
<tr>
<td>Mean</td>
<td>1.12</td>
<td>58</td>
<td>0.22</td>
<td>76.3</td>
<td>4.0</td>
<td>20.6</td>
<td></td>
</tr>
<tr>
<td>STDEV</td>
<td>0.10</td>
<td>3.8</td>
<td>0.06</td>
<td>1.3</td>
<td>0.0</td>
<td>1.1</td>
<td></td>
</tr>
</tbody>
</table>

STDEV – Standard deviation

### Table 3: Soil chemical properties as affected by mulching at harvest of castor bean.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>pH (H₂O)</th>
<th>Total Nitrogen (%)</th>
<th>Organic Carbon (%)</th>
<th>Organic Matter (%)</th>
<th>C/N Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palm bunch</td>
<td>6.65</td>
<td>0.28</td>
<td>1.04</td>
<td>1.79</td>
<td>3.71</td>
</tr>
<tr>
<td>Saw dust</td>
<td>6.90</td>
<td>0.28</td>
<td>1.16</td>
<td>2.00</td>
<td>4.14</td>
</tr>
<tr>
<td>Grass</td>
<td>7.00</td>
<td>0.56</td>
<td>1.04</td>
<td>1.79</td>
<td>1.86</td>
</tr>
<tr>
<td>Plastic mulch</td>
<td>6.45</td>
<td>0.28</td>
<td>0.55</td>
<td>0.94</td>
<td>1.96</td>
</tr>
<tr>
<td>No mulch</td>
<td>5.65</td>
<td>0.28</td>
<td>1.10</td>
<td>1.90</td>
<td>3.93</td>
</tr>
<tr>
<td>Mean</td>
<td>6.53</td>
<td>0.34</td>
<td>0.98</td>
<td>1.68</td>
<td>3.12</td>
</tr>
<tr>
<td>STDEV</td>
<td>0.54</td>
<td>0.13</td>
<td>0.24</td>
<td>0.43</td>
<td>1.12</td>
</tr>
</tbody>
</table>
Fig 1: Effect of mulching materials on percentage germination.

Fig 2: Effect of mulching materials on plant height.

Fig 3: Effect of mulching materials on number of leaves.

Fig 4: Effect of mulching materials on leaf area.
plant (806.5 kg ha\(^{-1}\)) and 75.3 g per plant (376.5 kg ha\(^{-1}\)), respectively. With the higher production cost associated with plastic mulching, mulching with sawdust or grass mulching may be more cost effective than the plastic mulching.

It is noted that the effects of mulching on different growth and yield components did have a consistent trend with treatments. Severino et al. (2011) also reported that an increase in one of these components does always result in a proportional increase in seed yield; probably because other components compensate.

**CONCLUSION**

The castor bean is currently a plant with a lot of uses and also a cash crop with high international demand. The Zibo Castor No.5 is an improved variety of castor developed in China. This research has shown that this variety of castor bean; a middle maturing hybrid variety bred by Zibo Academy of Agricultural Sciences can effectively be cultivated in Southern Nigeria. Mulching with different locally available materials have been shown to improve both the growth and yield of this plant and the physico-chemical properties of the soil cultivated to it. Out of the four mulching materials used, plastic mulching better improved most of the crop growth and yield parameters measured, while sawdust better enhanced soil properties. This research therefore suggests that this crop can be cultivated in the Niger Delta, for all its uses and as an export crop.

**REFERENCES**


