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Growth and yield impact of oyster mushroom *Pleurotus ostreatus* (Jacq P. Kumm) cultivated on different agricultural wastes

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ABSTRACT

Pleurotus ostreatus, an edible mushroom is an essential food product. Recognised as one of the cheapest sources of proteins, their high nutritional and anti-nutritional properties are of immense importance to humans. The present study evaluated the effect of sawdust and dried plantain leaves on the growth and yield of Pleurotus ostreatus. Sawdust and dried plantain leaves were composted into seven substrates; as single substrates and at different combinations. The composted substrates include sawdust 100 % (M_0), Dry plantain leaves 100% (M_1), Dry plantain leaves + sawdust at the ratio of 1:4 (M_2), 2:3 (M_3), 3:2 (M_4), 1:1 (M_5) and 4:1(M_6). Growth parameters of interest assessed flush include mycelia running rate (MRR), area of pileus, length of the stipe, the girth of the stipe, fresh weight and dry weight, number of fruit body, total yield and biological efficiency. At the end of the three weeks spawn running period, M_0 was overall best in supporting mycelia running rate with a mean MRR of 16.00 cm. M_1 substrates produced mushroom with longer and bigger stipes (7.17 cm) at the first flush. A higher number of fruit bodies (82.66), total yield (130.35 g), and biological efficiency (43.45 g) were all seen in M_0 substrates. Sawdust at 100 % (M_0) proved to be the best substrate for the cultivation of Pleurotus ostreatus.

Key Words: *Oyster mushroom, Sawdust, Plantain leaves, Biological efficiency and Substrates.*

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I. Introduction

Pleurotus ostreatus is a common edible mushroom belonging to the family pleurotaceae. Pleurotus species, commonly called oyster mushrooms are generally characterized by the ability to multiply and utilize various lignocellulosic waste, these species have been cultivated in different parts of the world (Frimpong-Manso et al., 2011; Shauket et al., 2012). The level of mushroom growth development is greatly dependent on environmental factors as well as the substrate type. Almost all agricultural wastes are available for cultivation of mushroom as they contain lignocellulosic substances (Agarwal et al., 2016). The ability of mushroom to convert high percentage of lignocellosic substrates to fruiting bodies increases profitability (Sharma et al., 2013).

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The disposal of agricultural waste has posed many problems in most developing countries Nigeria inclusive. Cultivation of edible mushrooms on agro-waste has been the best way of managing such wastes through bioconversion. Converting materials considered as wastes into valuable human food and some important commercial metabolites is a way of solving the nation's environmental pollution - associated challenges and hence affording us a cleaner ecosystem (Asemota et al., 2015; Eswaran and Ramabadran, 2000; Markson et al., 2012; Markson et al., 2017). Several researchers in the field of mushroom culture have reported varying impacts on mycelia running rate and growth parameters of *Pleurotus spp* on different substrates (Shah et al., 2004; Kimenju et al., 2009; Mondal et al., 2010; Ajonina and Tatah, 2012; Soniya et al., 2013; Markson et al., 2012; Markson et al., 2017).

Among the substrate materials identified as good sources for growing oyster mushroom, include rice straw, coffee pulps, sawdust, paper, etc. (Fan et al., 2000). Of these substrate materials, sawdust ranks as one of the best for the cultivation of oyster mushrooms worldwide, probably due to the level of the lignocelluloses materials available in them supporting the growth and development of mushrooms (Markson et al., 2017). However, there are other uses of sawdust, which could make them unavailable for mushroom cultivation such applications include wood pulp, poultry litter, etc. there is need to source for other substrates. This study was therefore conducted to evaluate the effect of dry plantain leaves and sawdust on the growth and yield of *Pleurotus ostreatus*.

II. Materials and Methods

Location of study

The research was carried out at JohnCollins farms located in Akpabuyo L. G. A. of Cross River State, Nigeria. Akpabuyo lies at latitude 4^0 54’3.31” N and longitude 8^0 28’52.00” E

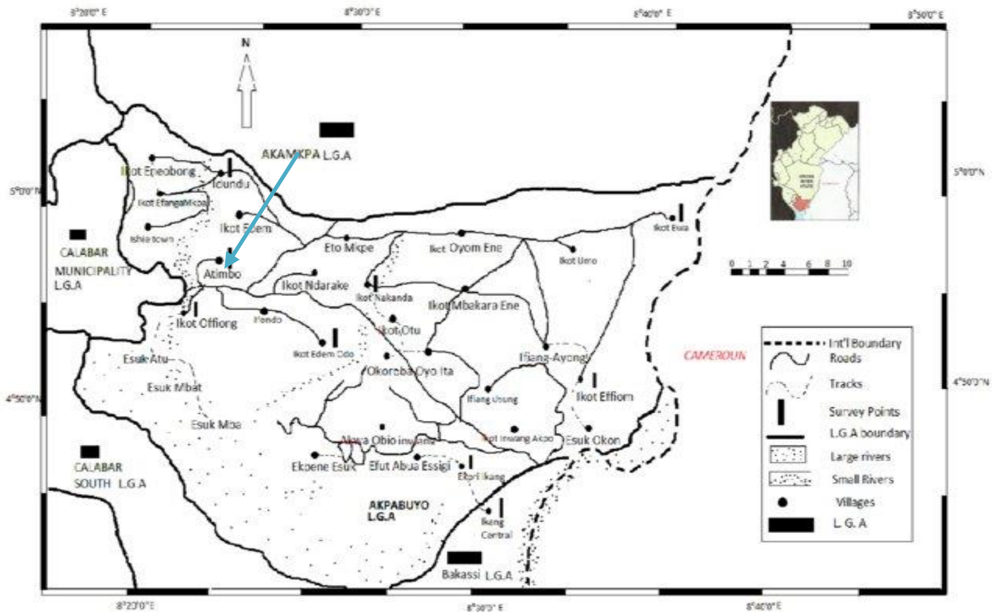

Figure 01. Map of Akpabuyo LGA, showing farm location

Composting of substrates for cultivation

Seven different types of unfermented substrates were composted according to the methods described by Markson et al. (2012) and Markson et al. (2017) with slight modifications. They include;

Sawdust 100% (M_0): Fresh sawdust obtained from sawmill was composted for one week by mixing of the sawdust every 2 days. Sawdust was soaked in water for 1 hour and drained to a moisture level of 70 %. For every 10 kg of sawdust, 2 kg of rice bran and 100 g of lime were added.

Dry plantain leaves 100% (M_1): Dry plantain leaves were shredded into tiny bits of about 1.5 cm to 2 cm soaked in water for 3 hours and compressed in sac bags to reduce moisture content. Ten kilograms (10 kg) of the leaves were weighed out, 1 kg of rice bran, and 50 g lime was added to the mixture and mixed thoroughly.

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Dry plantain leaves + sawdust at the ratio of 1:4 (M_2): One kilogram of dried plantain leaves was mixed with 1 kg of sawdust, 0.5 kg of rice bran, and 50 g of lime.

Dry plantain leaves + sawdust at the ratio of 2:3 (M_3): Two kilograms of dry plantain leaves were mixed with 3 kg of sawdust, 0.6 kg of rice bran, and 50 g of lime.

Dry plantain leaves + sawdust at the ratio of 1:1 (M_4): Two and a half kilogram (2.5 kg) of sawdust was mixed with 2.5 kg of dry plantain leaves, 1 kg of rice bran, and 50 g of lime.

Dry plantain leaves + sawdust at the ratio of 3:2 (M_5): Three kilograms of dry plantain leaves were mixed with 2 kg of sawdust, 0.6 kg of rice bran, and 50 g of lime.

Dry plantain leaves + sawdust at the ratio of 4:1 (M_6): Four kilograms of dry plantain leaves were mixed with 1 kg of sawdust, 0.8 kg of rice bran, and 50 g of lime.

Pasteurisation
Each of the composted substrates divided into 1 kg portions, filled into polypropylene (PP) bags measuring 30 x 11 cm were pasteurised at 121^0 C with drums for 1 hour and allowed to cool overnight.

Inoculation and spawn running (incubation)
Two teaspoons full of *Pleurotus ostreatus* spawn was placed aseptically on the previously pasteurised substrates after cooling. The end of the polypropylene bags was secured with a PVC pipe and sealed with cotton wool. The inoculated bags were kept at room temperature (28 ± 2^0 C) in a dark room for mycelia growth. Mycelia running rate was recorded in centimeters weekly.

Cropping
The bags were opened for fruiting after the mycelia had wholly covered the bags. The opened bags were stacked on wooden shelves and sprayed with clean water every three days. The cropping room was wetted with water daily to maintain a relative humidity of 75 %.

Harvesting
At maturity, mushrooms were harvested and relieved of traces of substrates attached to them before assessment using conventional methods based on the following parameters; area of pileus, length and of stipe, number of fruit bodies per bag, fresh weight (yield of mushroom) and dry weight.

Determination of total yield and biological efficiency
The total mushroom yield from each substrate was calculated by adding the fresh weights from all the five flushes. Biological efficiency was obtained using the formula

$$\text{Biological efficiency (\%)} = \frac{\text{Total weight of fresh fruit bodies}}{\text{Dry weight of substrates}} \times \frac{100}{1}$$

Experimental design and data analysis.
The experiment was a Completely Randomized Design (CRD) with three replications. Data collated were subjected to analysis of variance (ANOVA) using SPSS version 20.0, and one-way analysis of variance and Duncan's multiple range tests was used to compare the mean significant differences at $P\leq0.05$.

III. Results
Effect of substrate type on Mycelia running rate (MRR) and mycelia density
The result of mycelia running rate (MRR) of *P. ostreatus* cultivated on seven different substrate combinations after three weeks is shown in Table 01. In the first week, all the substrates had comparable MRR ($P\leq0.05$), except for M_2 substrate, which had the least MRR (5.07 cm/wk.). At weeks two and three, the MRR of *Pleurotus ostreatus* cultivated on sawdust was significantly higher ($P\leq0.05$) than all other substrates, with mean MRR values of 13.0 cm /wk and 16.00 cm/wk respectively. In

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terms of mycelium density, M_0 had very abundant and thick mycelium and was closely followed by M_4 substrate. Scanty mycelium density was observed in M_1, M_3, M_5, and M_6 substrates.

Effect of substrate type on the area of pileus of *P. ostreatus*

The area pileus of *P. ostreatus* cultivated on dry plantain leaves (M_1) substrate at the first flush was significantly lager ($P \leq 0.05$) than the area of pileus of mushrooms from all other substrate combinations. (M_2) supported mushrooms with the least pileus area (25.41 cm^2). At the second flush, M_5 and M_3 produced mushrooms with significantly lager pileus sizes than other substrates. M_3 and M_4 had the largest pileus size of 69.12 cm^2 and 45.39 cm^2 respectively and were significantly higher than other substrates at 3rd and 4th flushes. The smallest pileus size was observed in M_0 substrates at flushes three and M_2 at flushes one, two, and four. On the average, M_3 recorded the largest pileus area but did not differ statistically from M_4, M_5 and M_6 (Table 02).

Table 01. Effect of substrate combinations on the Mycelia Running Rate and mycelium density of *Pleurotus ostreatus*

	Mycelia running rate (cm/wk.)			
Substrates	Week 1	Week 2	Week 3	Mycelia density
M_0	$^*8.07^a \pm 0.67$	$13.00^a \pm 0.58$	$16.00^a \pm 0.58$	5+
M_1	$7.67^a \pm 0.33$	$12.33^{ab} \pm 0.44$	$15.00^{ab} \pm 1.15$	++
M_2	$5.67^b \pm 0.88$	$8.20^e \pm 0.40$	$9.77^c \pm 1.41$	3+
M_3	$8.40^a \pm 0.59$	$10.33^{cd} \pm 1.01$	$8.67^c \pm 1.41$	++
M_4	$7.90^a \pm 0.36$	$12.37^{ab} \pm 0.47$	$12.50^{abc} \pm 0.58$	4+
M_5	$8.03^a \pm 0.17$	$8.67^{de} \pm 0.44$	$9.00^c \pm 1.32$	++
M_6	$8.17^a \pm 0.17$	$10.67^{bc} \pm 0.73$	$11.50^{bc} \pm 2.08$	++

*Means of three replicates ± SEM. Means within each column followed by different letters are significantly different at $P \leq 0.05$ Duncan's multiple range test; MRR=mycelia running rate. ++ Scanty, 3+ moderate, 4+ abundant, 5+ very abundant

Table 02. Effects of substrate combinations on the area of Pileus of *Pleurotus ostreatus*

	Area of pileus (cm^2)					
Substrates	Flush 1	Flush 2	Flush 3	Flush 4	Flush 5	Average pileus size
M_0	$^*30.36^b \pm 0.32$	$37.16^{ab} \pm 0.98$	$19.14^d \pm 5.11$	$27.17^b \pm 4.06$	$20.15^a \pm 0.00$	$26.79^b \pm 1.61$
M_1	$51.42^a \pm 3.32$	$30.46^{ab} \pm 3.37$	$25.47 \pm^{cd} 4.35$	$22.12^{bc} \pm 2.32$	$0.00^b \pm 0.00$	$25.89^b \pm 1.02$
M_2	$25.41^b \pm 0.92$	$24.83^b \pm 0.39$	$20.04^d \pm 0.00$	$10.15^c \pm 0.00$	$0.00^b \pm 0.00$	$16.08^c \pm 0.20$
M_3	$32.83^{ab} \pm 5.26$	$46.47^a \pm 11.71$	$69.12^a \pm 0.54$	$15.00^{bc} \pm 0.00$	$0.00^b \pm 0.00$	$32.68^a \pm 1.56$
M_4	$36.45^{ab} \pm 3.16$	$36.82^{ab} \pm 0.93$	$41.18^{bc} \pm 5.02$	$45.39^a \pm 10.34$	$0.00^b \pm 0.00$	$31.97^a \pm 2.48$
M_5	$34.51^{ab} \pm 8.46$	$42.45^a \pm 4.84$	$32.09^{bcd} \pm 1.17$	$25.22^b \pm 0.00$	$20.23^a \pm 0.00$	$30.90^a \pm 1.69$
M_6	$39.44^{ab} \pm 10.52$	$40.49^{ab} \pm 4.17$	$46.62^b \pm 11.24$	$29.13^b \pm 3.81$	$0.00^b \pm 0.00$	$31.13^a \pm 4.41$

*Means of three replicates ± SEM. Means within each column followed by different letters are significantly different at $P \leq 0.05$ Duncan's multiple range tests

Effect of substrate combinations on stipe length of *Pleurotus ostreatus*

Table 03 shows the effect of different substrates combinations on the stipe length of *P. ostreatus.* M_1 Supported mushrooms with significantly ($P < 0.05$) longer stipes (7.17 cm) than those from other substrates at flush one. In contrast, at the second flush, there was no significant difference in the stipe length among mushrooms growing on all substrates. At the third flush, M_3 substrates produced mushrooms with the longest (5.50 cm) stipe were, however, not significantly different ($P \leq 0.05$) from other substrates except those on M_0 substrates which had the least stipe length of (2.17 cm). M_4 and M_5 were comparable ($P \leq 0.05$) and significantly longer than those on other substrates at flush four. At flush five, no growth was recorded for all substrates except for M_0 and M_5 where the stipe length was comparable. On the average, *P. ostreatus* grown on M_5 substrates had the longest stipe of 4.67 cm that was significantly different ($P \leq 0.05$) from all other substrates.

Effect of substrate types on the stipe girth of *Pleurotus ostreatus*

M_0 substrates produced mushroom with the biggest stipe girth at flush one with a mean value of 7.17 cm, which was significantly different ($P \leq 0.05$) from those growing on other substrates. At the second flush, M_0, M_3, and M_5 were comparable and significantly different from mushrooms on other substrates

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while M_2 supported mushrooms with the least girth value. At flushes three and four, M_2 and M_4 produce mushrooms with significantly bigger girth than other substrates. At flush five, M_5 produced mushroom with the most significant girth values, followed by M_0, whereas other substrates did not support any mushroom. There was no significant difference in the average stipe girth produced among substrates (Table 04).

Table 03. Effects of substrates on the stipe length of *Pleurotus ostreatus*

	Length of stipe (cm)					
Substrates	**Flush 1**	**Flush 2**	**Flush 3**	**Flush 4**	**Flush 5**	**Average stipe length (cm)**
M_0	*3.38^{d}±0.73	4.40^{a}±0.10	2.17^{c}±0.17	3.00^{b}±0.00	3.00^{b}±0.00	3.19^{cd}±0.60
M_1	7.17^{a}±0.17	4.23^{a}±0.73	4.33^{ab}±0.83	3.25^{b}±0.43	0.00^{c}±0.00	3.70^{b}±0.20
M_2	4.33^{cd}±0.33	3.90^{a}±0.38	5.00^{ab}±0.00	1.50^{c}±0.00	0.00^{c}±0.00	2.94^{d}±0.10
M_3	6.60^{ab}±0.87	3.83^{a}±0.60	5.50^{a}±0.50	1.83^{c}±0.17	0.00^{c}±0.00	3.55^{ab}±0.27
M_4	5.50^{bc}±0.29	3.23^{a}±0.15	4.50^{ab}±0.00	5.00^{a}±0.76	0.00^{c}±0.00	3.64^{ab}±0.16
M_5	4.57^{cd}±0.23	3.53^{a}±0.29	3.73^{ab}±0.62	5.00^{a}±0.00	5.50^{a}±0.00	4.67^{a}±0.21
M_6	5.50^{bc}±0.50	4.10^{a}±0.37	4.33^{ab}±0.33	3.00^{b}±0.28	0.00^{a}±0.00	3.39^{bcd}±0.94

*Means of three replicates ± SEM. Means within each column followed by different letters are significantly different at P≤0.05 Duncan's multiple range tests

Table 04. Effect of substrate combinations on the stipe girth of *Pleurotus ostreatus*

	Girth of stipe (cm)					
Substrates	**Flush 1**	**Flush 2**	**Flush 3**	**Flush 4**	**Flush 5**	**Average stipe girth (cm)**
M_0	*3.46^{bc}±0.33	3.33^{a}±0.88	1.50^{c}±0.00	2.50^{bc}±0.00	2.17^{b}±0.17	2.59^{a}±0.29
M_1	7.17^{a}±0.17	2.13^{bc}±0.32	2.67^{bc}±0.17	2.25^{bc}±0.43	0.00^{c}±0.00	2.84^{a}±0.23
M_2	4.50^{b}±0.29	1.93^{c}±0.67	4.33^{a}±0.67	3.00^{b}±0.00	0.00^{c}±0.00	2.75^{a}±0.18
M_3	3.00^{c}±0.29	3.17^{a}±0.73	3.23^{ab}±0.54	2.50^{bc}±0.00	0.00^{c}±0.00	2.38^{a}±0.31
M_4	3.67^{bc}±0.67	2.50^{abc}±0.00	3.58^{ab}±0.46	3.83^{a}±0.44	0.00^{c}±0.00	2.71^{a}±0.25
M_5	2.67^{c}±0.33	3.53^{a}±0.29	2.67^{bc}±0.17	2.00^{c}±0.00	2.50^{a}±0.00	2.67^{a}±0.15
M_6	3.30±^{c}0.15	2.50^{abc}±0.28	3.00^{b}±0.29	3.00^{b}±0.29	0.00^{c}±0.00	2.36^{a}±0.18

*Means of three replicates ± SEM. Means within each column followed by different letters are significantly different at P≤0.05 Duncan's multiple range tests

Effect of substrate types on the fresh weight, total yield and biological efficiency of *Pleurotus ostreatus*

Table 05 shows the effects of the combination of the different substrates on the fresh weight, total yield, and biological efficiency of *P. ostreatus*. At the first flush, M_0 and M_4 substrates produced mushrooms with fresh weights values that were significantly higher (P≤0.05) than those on other substrates combinations. At the second and third flushes, M_0 had mushrooms with the highest fresh weights of 29.20 g and 24.37 g, respectively, compared with other substrates. At the fourth flush, M_4 was best while M_5 and M_0 were best at the fifth flush. Other substrates did not produce any growth beyond the fourth flush. The highest yield (130.35 g) and biological efficiency of 43.45 g were obtained from *Pleurotus ostreatus* cultivated on M_0 substrates, which significantly differ (P≤0.05) from other substrate combinations. On the whole, M_2 had the least yield.

Effect of substrate types on the dry weight of *Pleurotus ostreatus*

The result of the dry weights of *P. ostreatus*, as influenced by the various substrates, is presented in Table 06. M_0, M_1, and M_4 had dry weights that were significantly higher than those obtained from other substrates at flush one. At flushes 2 and 4, mushrooms produced on M_4 substrates was significantly different in weight than others. At flush 3, there was no significant difference among the substrates. However, on average, M_0 had the highest dry weight.

Effect of substrate types on the number of fruit bodies of *Pleurotus ostreatus* produced.

At the first and third flushes, M_0 substrates produced a significantly higher number of mushrooms than those recorded on other substrates. At the second flush, M_2 and M_4 produced a significantly higher number of fruit bodies than seen on other substrates except for the records obtained from M_0

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and M_1 treatments. All other substrates were comparable at the fourth flush except for M_3, and at the fifth flush, only M_5 and M_0 produced mushrooms (Table 07). On average, M_0 substrate produced the highest number of fruit bodies with a mean value of 88.66 and was closely followed by M_4, while M_3 produced the least amount.

Table 05. Effects of substrates on the fresh weight (yield) and biological efficiency of *P. ostreatus*

Substrates	Fresh weight (g)/Flushes					Total yield (g)	Biological efficiency (%)
	Flush 1	Flush 2	Flush 3	Flush 4	Flush 5		
M_0	*49.63^{a}±1.41	29.20^{a}±0.38	24.37^{a}±2.39	9.45^{b}±0.20	17.70^{a}±0.00	130.35^{a}±1.04	43.45^{a}±0.49
M_1	43.40^{ab}±1.31	19.52^{b}±0.97	11.13^{c}±0.59	5.53^{b}±1.87	0.00^{b}±0.00	79.58^{c}±2.07	26.52^{bc}±5.95
M_2	15.07^{d}±3.50	17.13^{b}±0.56	14.10^{c}±0.80	3.40^{b}±0.00	0.00^{b}±0.00	62.57^{d}±3.15	20.85^{d}±3.59
M_3	30.73^{c}±6.51	16.97^{b}±3.44	21.00^{ab}±0.75	4.10^{b}±0.00	0.00^{b}±0.00	72.80^{c}±8.94	24.23^{d}±3.15
M_4	49.67^{a}±4.81	22.55^{b}±1.57	16.37^{bc}±4.47	16.33^{a}±0.54	0.00^{b}±0.00	104.92^{b}±7.66	34.97^{b}±3.01
M_5	30.13^{c}±4.07	9.41^{c}±0.67	13.18^{c}±0.39	11.75^{b}±2.00	16.20^{a}±0.00	80.37^{c}±6.65	26.79^{abc}±1.20
M_6	32.43^{bc}±1.12	17.50^{b}±3.44	10.93^{c}±1.85	11.73^{b}±1.05	0.00^{b}±0.00	72.60^{c}±1.74	24.15^{cd}±0.62

*Means of three replicates ± SEM. Means within each column followed by different letters are significantly different at P≤0.05 Duncan's multiple range tests

Table 06. Effect of substrate type on the dry weight of *Pleurotus ostreatus*

	Dry weight (g)/Flushes					
Substrates	Flush 1	Flush 2	Flush 3	Flush 4	Flush 5	Average dry weight
M_0	5.27^{a}±0.12	2.90^{ab}±0.26	1.93^{a}±0.88	1.20^{bc}±0.58	2.20^{a}±0.58	2.70^{a}±0.61
M_1	4.63^{a}±0.13	2.20^{b}±0.15	1.77^{a}±0.24	0.83^{cd}±0.26	0.00^{b}±0.00	1.89^{c}±0.77
M_2	1.97^{b}±0.23	1.80^{b}±0.12	2.10^{a}±0.75	0.50^{d}±0.50	0.00^{b}±0.00	1.27^{d}±0.13
M_3	2.20^{b}±0.66	1.83^{b}±0.41	1.70^{a}±0.42	0.80^{c}±0.00	0.00^{b}±0.00	1.31^{d}±0.19
M_4	4.17^{a}±0.48	3.83^{a}±0.33	1.17^{a}±0.27	2.23^{a}±0.12	0.00^{b}±0.00	2.28^{b}±0.13
M_5	2.70^{b}±0.13	1.43^{b}±0.88	1.53^{a}±0.15	1.53^{b}±0.26	1.50^{a}±0.00	1.74^{c}±0.05
M_6	2.87^{b}±0.26	1.80^{b}±0.25	1.80^{a}±0.58	1.47^{b}±0.12	0.00^{b}±0.00	1.59^{cd}±0.47

*Means of three replicates ± SEM. Means within each column followed by different letters are significantly different at P≤0.05 Duncan's multiple range test

Table 07. Effect of substrate type on the number of *Pleurotus ostreatus* fruit bodies produced

	Number of fruit bodies/flushes/Total number of fruit bodies					
Substrates	Flush 1	Flush 2	Flush 3	Flush 4	Flush 5	Total number
M_0	*45.00^{a}±2.89	10.33^{ab}±0.88	22.33^{a}±3.67	4.00^{a}±0.58	1.00^{b}±0.00	82.66^{a}±0.29
M_1	8.00^{e}±1.53	10.67^{ab}±1.20	9.00^{b}±0.58	4.00^{a}±1.15	0.00^{c}±0.00	38.00^{cd}±0.18
M_2	9.33^{de}±0.67	13.00^{a}±2.52	4.33^{b}±0.67	3.00^{ab}±0.00	0.00^{c}±0.00	29.66^{cd}±0.64
M_3	14.00^{cd}±1.15	5.33^{c}±0.67	6.33^{b}±0.67	1.00^{b}±0.00	0.00^{c}±0.00	26.66^{d}±0.48
M_4	19.33^{b}±0.33	12.33^{a}±0.88	9.33^{b}±0.33	3.67^{a}±0.67	0.00^{c}±0.00	44.66^{b}±0.44
M_5	16.33^{bc}±1.20	5.00^{c}±2.08	4.67^{b}±0.67	3.00^{ab}±0.00	4.00^{a}±0.00	32.93^{cd}±0.23
M_6	21.33^{b}±1.86	6.00^{bc}±1.00	4.33^{b}±0.67	3.67^{a}±0.29	0.00^{c}±0.00	35.33^{c}±0.70

*Means of three replicates ± SEM. Means within each column followed by different letters are significantly different at P≤0.05 Duncan's multiple range test.

IV. Discussion

Mycelia running rate is an essential phase of mushroom cultivation since it determines the extent to which mushroom production will last as substrates with thicker mycelium density tend to produce for longer period of time. In this study, mycelia-running rate of *P. ostreatus* varied remarkably on the seven different substrate combinations. Sawdust substrate recorded the fastest mycelia growth from the second week during the mycelia growth period (incubation period). This result is in line with (Debu et al., 2014), who reported the fastest mycelia running rate of *P. ostreatus* in mahogany sawdust. The result from this study differed from that of (Mondal et al., 2010) who reported that mycelia running rate of *Pleurotus ostreatus* was fastest in banana leaf and rice straw than sawdust and (Hoa et al., 2015) who said that corncobs and sugar cane bagasse was the most suitable substrates for the cultivation of *Pleurotus* species.

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One of the contributing characteristics of mushroom yield is the pileus size (Ajoninah and Tatah, 2012). The substrate effect on the area of pileus at different flushes showed significant differences in the pileus size among the substrates. Assessment of the influence of substrate combination on the growth of *P. ostreatus* revealed that the pileus sizes (area) were lager in M_1 substrates at the first flush only. Mondal et al. (2010) observed a similar trend of bigger pileus diameter of *P. ostreatus* on sawdust substrates at the first flush. However, the highest pileus area (69.12 cm^2) was recorded in M_3 of the third flush, and the least was in M_0 substrates of the third flush. The increase in pileus size at the third flush could be because of the decrease in the nutrient content of the substrate as well as the decrease in quantity of mushroom produced. This result corresponds with that of Kimenju et al. (2009), who reported that the fewer the mushroom, the wider the pileus. In this study, pileus size did not decrease as mushroom harvest progressed as published by Ajoninah and Tatah (2012).

The average stipe length ranged from 2.9 cm in M_2 to 4.67 cm on M_3. The result reveals that the plantain leaves to sawdust ratio greatly influenced the stipe length. Although M_1 had a longer stipe at the first flush, that reduced as the flushes progressed, it indicated that more nutrients were available for the mushroom, in the first flush. The results differ from the report of Ambi et al. (2011), who observed shorter stipes for *P. ostreatus* grown on some sawdust substrates. The average stipe girth of the mushroom produced on the different substrates did not differ significantly from each other (Table 4). However, plantain leaves produced mushrooms with bigger stipe at the first flush. Preferred mushrooms with marketable quality are those with bigger pileus, shorter but bigger stipes (Agba, 2019).

Fresh weight assessment showed that there were disparities at different flushes. The reason for this could be the availability of nutrients in the substrates at a particular time. The nutrient content of the substrates decreased as the number of flushes increased. The total yield which is the addition of all fresh weights from different flushes is one of the parameters used by farmers to ascertain profitability. Biological efficiency is a simple way to calculate the effectiveness of mushroom strain and substrates combination and occurs when there is harvest of 1 kg of mushroom from 1 kilogram of substrates (Fadnadzo, 2010). In this study, M_0 substrate gave the best yield and biological efficiency this was closely followed by M_4 substrates. The excellent performance of these two substrates could be attributed to the high mycelial density they exhibited during spawn run (Thomas et al., 1988; Familoni et al., 2018). However, Obodai et al. (2003) reported that total yield and biological efficiency did not correspond with mycelia colonisation. Akinmusire et al. (2011) reported a low yield of Pleurotus pulmonarius on sawdust as compared to our present study. Kortei et al. (2014) reported a relatively higher BE of 65-98 % than the BE of this study. The dry weight of the mushroom was obtained by drying the fresh mushrooms in an oven at 30^0 C for 6 hours. Due to poor preservation methods, it is necessary to ascertain the dry weights of mushroom after harvest. In this study, M_0 substrates and M_4 gave the best dry weights of 2.70 g and 2.28 g, respectively.

Generally, the increase in the number of fruit bodies produced per flush was not consistent from flush to flush, as shown in table 07. However, the total number of fruit bodies recorded showed that M_0 had the highest mean value of fruit bodies (82.66). The variation in different flushes could be that the amount of N:C ratio in the substrates after each flush must have influenced the level of degradation, which in turn affected the quantity of mushroom produced. Frimpong-Manso et al. (2011) reported that the number of fruit bodies produced per flush decreased from flush to flush. Other researchers have also said the number of fruit body production between the ranges of 2.73-28.66 (Bhatti et al 2007; Kanhar et al., 2007). Musakhail et al. (2011) also reported fruit body production of *Pleurotus ostreatus* on substrates amended with gram powder at an average of 12.50-56.25.

V. Conclusion

The profitability of mushroom agri-business is dependent on the yield and biological efficiency. Any substrate which gives very high yield and biological efficiency is considered a good substrate for cultivation of a particular mushroom species. This study discovered that aside the excellent performance by sawdust substrates, a combination of the two substrates at equal ratio could be used as alternative substrates for the cultivation *P. ostreatus*

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