Asian Journal of Agricultural and Horticultural Research

7(1): 38-49, 2020; Article no.AJAHR.61854
ISSN: 2581-4478

Vermicompost-enriched Substrate Improves the Production of Milky Mushroom (*Calocybe indica*)

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Authors' contributions

This work was carried out in collaboration among all authors. Author SS conceived, designed, and performed the experiment and prepared the manuscript. Author AHM actively participated in executing the experiment and prepared manuscript. Author NCS designed and monitored the experiment. Authors RM and BNS analyzed the data and author FMA conceived, designed and supervised the experiment. All authors read and approved the final manuscript.

Article Information

DOI:10.9734/AJAHR/2020/v7i130088
Editor(s):
(1) Dr. Magdaléna Valšíková, Slovak University of Agriculture (SUA), Slovakia.
Reviewers:
(1) Javier Augusto Vera Solano, Universidad de Pamplona, Colombia.
(2) Marcos Vinicius Winckler Caldeira, Federal University of Espirito Santo, Brazil.
Complete Peer review History: http://www.sdiarticle4.com/review-history/61854

Received 02 August 2020
Accepted 07 October 2020
Published 27 October 2020

Original Research Article

ABSTRACT

Aims: We investigated most suitable substrate (wheat and rice straw) enriched with vermicompost and their different levels (10%, 25%, 50%, 75% and 100%) for enhancing production of milky mushroom.

Study Design: The experiment was designed by following single factor Randomized Complete Block Design (RCBD).

Place and Duration of Study: The experiment was conducted in a mushroom culture house to observe the growth and productivity of highly potential milky mushroom by using different vermicompost enriched substrate during March-October, 2017

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Methodology: Based on the different treatment combinations the quantity of substrate and vermicompost on volume basis were used per packet with 5% spawn. Coco dust was used as casing material. After incubation, matured fruiting bodies were harvested and data were recorded on growth and yield parameters.
Results: The addition of vermicompost with rice substrates improved the diameter of pelius 32-74%, thickness of pelius 26- 60%, diameter of stipe 24-55% and length of stipe 25 to 95% relative to the unsupplemented substrate. Similarly, vermicompost supplementation with wheat straw substrates increased the diameter of pelius 27-71%, thickness of pelius 11- 40%, diameter of stipes 21-56% and length of stipe 17- 72% relative to the unsupplemented substrate at any harvest. Supplementation of vermicompost reduced the duration for spawn run 11-55% in wheat straw and 11- 49% in rice straw compared with non-supplemented one. Furthermore, pin head initiation became quicker 26- 66% in wheat straw and 15- 61% in rice straw. In addition, total number of fruiting body increased from 6- 82% in wheat straw supplemented with different doses of vermicompost, while rice straw increased total number of fruiting body ranged from 17- 39% compared to unsupplemented one. The addition of 10%, 25%, 50% and 75% levels of vermicompost with wheat straw increased the fresh yield of *C. indica* by 23%, 54%, 121% and 73%, respectively compared to wheat straw alone; however, similar levels of vermicompost with rice straw increased the fresh yield of *C. indica* by 31% , 63%, 112% and 87%, respectively compared to rice straw alone. The biological efficiency of *C. indica* also did exhibit significant differences ranged between 65-160% among different levels of vermicompost supplementation with rice and wheat straw substrates.
Conclusion: The result revealed that increasing the vermicompost level lead to a less biological efficiency and yield, but it remains higher than the control (straw alone). It is additionally conceivable that the application of vermicompost to substrates with lower levels would provide an even better yield, without adversely affecting the bioefficiency of the harvested mushrooms. These judges, however, need more work to validate reliability.

Keywords: Biological efficiency; C/N ratio; edible mushroom; organic manure; rice straw; wheat straw; organic vegetable; nutrient management.

1. INTRODUCTION

Conversion of lignocellulosic residues from agriculture and forest sector into mushrooms is one of the best biotechnological processes to address the protein based food demand in an economical and sustainable way. World production of cultivated, edible mushrooms is 8993280 tonnes [1] but the demand is higher than that because it has increased 11 fold since 1970 [2]. Therefore, milky white mushroom (*Calocybe indica* P and C) could play an important role in satisfying the growing market demands for edible mushrooms in the near future because of its incomparable productivity and high shelf life.

A substrate is an important substance for making spawn and growing mushrooms. Various kinds of agricultural wastes, including wheat straw, paddy straw, maize, bajra, cotton stalks and leaves, sugarcane bagasse, dehulled maize cobs, tea and coffee waste and coconut coir substrate can be utilized for cultivation of *C. indica* [3]. It is found that the wheat straw substrate was superior which recorded highest biological efficiency 146.3% and paddy straw was the next best superior substrate for cultivation of milky mushroom [4]. Though, some researcher [5] reported that the rice straw was the best substrate for the commercial cultivation of *C. indica*. The conventional substrates fails to deliver the required amount of macro and micronutrients including the vital NKP to plants in shorter time but the conventional compost fails to deliver the required amount of macro and micronutrients including the vital NKP to plants in shorter time but the vermicompost dose and it can retains nutrients for longer time [6].

Earthworms ingest wastes, digest them in the gut and defecate out faecal matter which is termed as “Vermicompost”. *Eudrilus eugineae* (Kinberg), *Eisenia fetida* (Savigny) and *Perionyx excavatus* (Perrier) are considered as the efficient species of earthworm for Vermiculture [7]. It is proving to be highly nutritive organic fertilizer and more powerful growth promoter over the conventional composts and a protective farm input. It helps to increase the physical, chemical and biological properties of soil thus, restore and improve the natural fertility of soil against the destructive chemical fertilizers, which has destroyed the soil properties over the years. Vermicompost is rich in NKP (nitrogen 2-3%, potassium 1.85-2.25% and phosphorus 1.55-2.25%), micronutrients, beneficial soil microbes and also contain plant growth hormones and enzymes [6]. It is scientifically proven as miracle growth promoter and also plant protector from pests and diseases. Vermicomposts are rich in macro and micro nutrients, beneficial microflora besides containing growth promoting substances [6]. Though vermicompost has been used as a casing material, but it has a limited use as a substrate [8,9].

To increase the production, a variety of substrates along with supplements were tested, but limited success has been found. As there is an absolute need for improvement in the yield potentials of milky mushroom before its commercial ventures. Therefore, the current study was conducted for investigating the most suitable substrates and appropriate use of vermicompost as a supplement in the production of highly potential milky mushroom.

2. MATERIALS AND METHODS

2.1 Pure Culture and Maintenance

The pure cultures of *C. indica* were obtained from Mushroom Development Institute (MDI), Savar, Dhaka and augmented on PDA (Potato Dextrose Agar) medium by frequent sub-culturing. The culture was maintained at 28 ± 2 °C in the incubator.

2.2 Seed Material Preparation

Spawn, a seed material for mushroom cultivation was prepared. For this purpose, uninfested and clean wheat grains were boiled with equal amount of water till grains become soft but were not allowed to split open. The moisture content of boiled grains was allowed to leave as such for hours for air drying so that water on surface is evaporated to obtain 50 to 55% moisture. Then the grains are mixed with 0.5% calcium carbonate and 2.0% calcium sulphate so that the pH of the grains is around 7.0 to 7.8 and they do not form clumps. First gypsum and chalk powder are mixed separately and then they are thoroughly mixed with grains. This substrate was filled into glucose bottles or 15 × 20 cm size polypropylene bags. The mouth part of the container was plugged with clean, non-absorbent cotton. These bottles were sterilized for one hour at 22 pound pressure (126 ºC). Upon cooling for 24 hours, the content was inoculated with bits of fresh fruiting culture of *C.indica* under aseptic condition. The containers were incubated for 23-28 days to attain complete ramification over the substrate at 26-28 ºC. These seed materials were used freshly for cultivation of aforementioned mushroom.

2.3 Experimental Site and Treatments

The experiment was conducted in a mushroom culture house to observe the growth and productivity of highly potential milky mushroom by using different vermicompost enriched substrate. The experiment was designed by following single factor Randomized Complete Block Design (RCBD). Eleven treatments were applied and each treatment was replicated three times. Treatment combinations were shown in Table 1.

Table 1. Treatment combinations used in this study

Treatments	Combinations	Treatments	Combinations
T_1	Wheat straw (100%)	T_7	Rice straw (75%) + vermicompost (25%)
T_2	Wheat straw (90%) + vermicompost (10%)	T_8	Rice straw (90%) + vermicompost (10%)
T_3	Wheat straw (75%) + vermicompost (25%)	T_9	Rice straw (25%) + vermicompost (75%)
T_4	Wheat straw (50%) + vermicompost (50%)	T_{10}	Rice straw (50%) + vermicompost (50%)
T_5	Wheat straw (25%) + vermicompost (75%)	T_{11}	vermicompost (100%)
T_6	Rice straw (100%)		

The locally available lingo-cellulosic substrates such as wheat straw and rice straw were selected. Vermicompost produced by *Eudrillus eugineae* in brick wall above ground vermiculture was obtained from vermicuture unit located at Savar, Dhaka, Bangladesh. About 560 g of substrate on dry weight basis was used per packet. The selected substrates were filled in thin gunny bags and soaked in soaking water tank for 12-14 hours. Then the bags were removed, water was drained and the substrates were autoclaved for 2 hours at 121 °C. After autoclaving bags were opened and the straw was spread on a table for 5-6 hours allowed to cool.

2.4 Inoculation and Growth Condition

Based on the different treatment combinations the quantity of substrate and vermicompost on volume basis were used per bed with 5% spawn. Slow growing supplements like vermicomposts are most commonly applied at the end of the substrate preparation, prior to spawning, to promote the vegetative growth throughout the substrate [10]. The increase in temperature immediately after supplementing was controlled by making some perforations into the packets. Coco dust was used as casing material which was chemically sterilized by drenching with 2% formalin solution two weeks before using were exposing the casing soil for the escape of the excessive formalin into the atmosphere. The pH of the medium was adjusted from 7.0 to 8.5. For determination of pH, 10 g of casing samples was collected on the day of casing from casing material used, 100 ml of distilled water was added in every sample and shaken well. The suspensions were kept for one hour at room temperatures and pH of the sample was measured using an electronic digital pH meter (Electronic Instrument Limited). Then it was added over the mycelial impregnated substrate from 1 cm to 4 cm thickness.

2.5 Incubation and Observation

After casing, the filled bags were shifted to the cropping room where temperature of 25-32 °C and relative humidity of 85-90% were maintained. During fruiting, 3-4 fresh air circulations were given in the cropping room. Light watering was done twice a day and ruffling of the casing soil surface was done intermittently for good aeration. Matured fruiting bodies were harvested and observations regarding the number and average fruiting body weight were recorded. Biological efficiency was calculated as a ratio between the fresh weight of harvested mushrooms and the dry weight of substrate per bag and was expressed in percent.

2.6 Statistical Analysis

The data were analyzed using statistical software R-analytics by subjecting them to one way analysis of variance (ANOVA). The mean comparisons were carried out using Fisher's Least Significant Difference (LSD) test, where $P \leq 0.05$ was considered significant.

3. RESULTS AND DISCUSSION

3.1 PeliusSize of Milky Mushroom

Average diameter of pelius of different treatments at different harvest differed significantly, which was ranged from 5.5 cm to 10.37 cm (Table 2). Fifty percent vermicompost supplementation 70%, 86% and 80% increase in pelius diameter compared to rice straw alone at the different harvest (1st, 2nd and 3rd, respectively). Similarly, vermicompost addition increased 59%, 72% and 85% in the pelius diameter in case of wheat straw at the different harvest (1st, 2nd and 3rd, respectively). Vermicompost supplementation at 75% with rice straw and wheat straw also gave promising increase (39-77%) in pelius diameter compared to rice straw alone and 37- 64% increase in pelius diameter compared to wheat straw at any harvest, respectively. Pelius diameter was increased 36-52% and 26- 41% at any harvest when rice straw was supplemented with 25% and 10% vermicompost, respectively. Similarly, vermicompost addition gave increase ranging between 26- 36% (@25% supplementation) and 23-32% (@10% supplementation) in pelius diameter over wheat straw alone. Surprisingly, when mushroom was grown only in vermicompost pelius diameter increased 15% and 34% compared to rice straw and wheat straw alone, respectively. Different doses (10%, 25%, 50% and 75%) of vermicompost addition with rice straw gave 15% to 67% increase in pleius thickness at different harvest (1st, 2nd and 3rd). Similarly, vermicompost supplementation with wheat straw gave 9% to 42% increase in pelius thickness over wheat straw substrates.

Table 2. Effect of vermicompost-enriched substrates on size of pelius of milky mushroom

Treatments	Pelius diameter (cm)				Pelius thickness (cm)			
	1st harvest	2nd harvest	3rd harvest	Average	1st harvest	2nd harvest	3rd harvest	Average
T_1	6.18 cd	6.30 ef	5.67 ef	6.05 fg	1.98 ab	1.87 d	2.03 bc	1.96 de
T_2	7.74 a-d	7.73 cd	7.47 c-f	7.65 de	2.16 ab	2.20 a-d	2.17 abc	2.18 bcd
T_3	8.40 abc	7.93 cd	7.70 bcd	8.013 cde	2.42 ab	2.46 abc	2.52 ab	2.46 abc
T_4	9.83 a	10.82 a	10.47 a	10.37 a	2.73 a	2.65 a	2.83 a	2.74 a
T_5	9.37 ab	8.65 bc	9.28 abc	9.10 abc	2.57 a	2.53 ab	2.60 ab	2.57 ab
T_6	5.28 d	5.57 f	5.65 f	5.50 g	1.63 b	1.73 d	1.60 c	1.66 e
T_7	8.00 abc	7.91 cd	7.67 bcde	7.86 cde	2.10 ab	2.43 abc	2.47 ab	2.33 a-d
T_8	7.42 a-d	7.00 de	7.33 c-f	7.25 def	2.10 ab	2.00 bcd	2.17 abc	2.09 cd
T_9	9.33 ab	8.29 cd	7.83 bcd	8.49 bcd	2.56 a	2.48 abc	2.60 ab	2.55 ab
T_{10}	9.47 ab	9.83 ab	9.50 ab	9.60 ab	2.67 a	2.63 a	2.67 ab	2.66 a
T_{11}	7.08 bcd	6.98 de	6.80 def	6.95 ef	2.03 ab	1.93 cd	2.13 abc	2.03 de
CV	19.34	9.78	15.24	9.99	20.45	14.45	18.80	10.38
LSD	2.64	1.32	2.01	1.34	0.79	0.56	0.75	0.41

**means (±sd) were calculated from three replicates for each treatment. values with different letters are significantly different at p ≤ 0.05 applying the fisher's lsd test. here, T1=wheat straw (100%), T2 = wheat straw (90%) + vermicompost (10%), T3 = wheat straw (75%) + vermicompost (25%), T4 = wheat straw (50%) + vermicompost (50%), T5 = wheat straw (25%) + vermicompost (75%), T6 = rice straw (100%), T7 = rice straw (75%) + vermicompost (25%), T8 = rice straw (90%) + vermicompost (10%), T9 = rice straw (25%) + vermicompost (75%), T10 = rice straw (50%) + vermicompost (50%), T11 = vermicompost (100%)*

3.2 Stipe Size of Milky Mushroom

Different levels (0%, 10%, 25%, 50% and 75%) of vermicompost supplementation with rice and wheat straw substrate created difference in diameter of stipe ranged from 2.10 to 4.93 cm (Table 3) at different harvest. When vermicompost is added with wheat straw @10%, 25%, 50% and 75% it helped to increase diameter of pelius from 9-58%, 16-30%, 45-65% and 31-51% compared to wheat straw alone, respectively. Similarly, supplementation of rice straw with vermicompost at same doses produced difference in stipe diameter ranged from 14- 37% (@10%), 28- 40% (@25%), 27-88% (@50%) and 28- 40% (@75%) at different harvest. Length of stipe also varied with different levels of vermicompost application ranged from 17.50 cm to 7.25 cm (Table 2).

3.3 Average Weight of Each Sporophore of Milky Mushroom

The average weight of each sporophore of C. indica did exhibit significant difference among treatments ranged from 52 g to 107 g (Fig. 1). Vermicompost supplementation did positive and negative effects on the average weight of individual sporophore. Different doses of vermicompost supplementation with wheat straw increased the average weight of each sporophore of *C. indica* ranged from 1% -28% compared to wheat straw alone. Similarly, addition of vermicompost as a supplement with rice straw substrate increased 3%- 67% compared to rice straw alone.

3.4 Spawn Run, Pin Head Initiation and Number of Total Fruiting Body per Packet

The period for spawn run in *C. indica* significantly varied with respect to different levels of vermicompost addition to different substrates (rice straw and wheat straw) used from 11 days to 28 days (Fig. 2). Spawn run was faster (11 days) in wheat straw substrate supplemented with 50% vermicompost. Time required for pin head initiation differed significantly with respect of different level of supplementation. Pin head initiation was quicker (7 days) in wheat straw substrate supplemented with 50% vermicompost which was followed by rice straw supplemented with 50% vermicompost (9 days) and 75% supplementation with wheat straw (11 days). However, spawn run and pin head initiations were significantly delayed (28 days and 23 days) in treatment T11 (Vermicompost 100%). Total number of fruiting body per packet varied from 5 to 10 (Fig. 2). Total number of fruiting body increased from 6% to 82% in wheat straw

Table 3. Effect of vermicompost-enriched substrates on size of stipe of milky mushroom

Treatments	Stipe diameter (cm)				Stipe length (cm)			
	1st harvest	2nd harvest	3rd harvest	Average	1st harvest	2nd harvest	3rd harvest	Average
T_1	2.99 cd	2.61bc	2.60 cd	2.73 ef	10.22 f	9.37 e	10.50 f	10.03 h
T_2	4.72 ab	2.87 abc	2.83 cd	3.47 bcd	11.72 e	11.18 d	12.17 e	11.69 f
T_3	3.47 cd	3.40 abc	3.07 bc	3.31 b-e	14.00 c	13.03 c	14.33 c	13.79 d
T_4	4.93 a	3.80 a	4.07 a	4.27 a	17.50 a	16.83 a	17.50 a	17.28 a
T_5	3.90 abc	3.67 ab	3.94 a	3.84 ab	15.94 b	15.33 b	16.22 b	15.83 b
T_6	2.69 d	2.41 c	2.10 d	2.40 f	8.90 g	7.723 f	9.35 g	8.66 i
T_7	3.43 cd	3.12 abc	2.93 bc	3.16 cde	12.83 d	12.25 c	13.33 d	12.80 e
T_8	3.32 cd	2.73 abc	2.88 bcd	2.98 def	10.99 ef	10.47 d	11.13 f	10.86 g
T_9	3.68 bcd	3.43 abc	3.67 ab	3.59 bc	15.29 b	14.45 b	15.40 b	15.04 c
T_{10}	3.42 cd	3.80 a	3.95 a	3.73 abc	16.93 a	16.37 a	17.37 a	16.89 a
T_{11}	3.07 cd	2.68 abc	2.75 cd	2.84 ef	8.07 h	7.25 f	8.10 h	7.81 j
CV	18.06	20.96	14.87	10.88	3.73	4.74	3.98	2.78
LSD	1.11	1.12	0.801	0.61	0.82	0.99	0.90	0.60

**means (±sd) were calculated from three replicates for each treatment. values with different letters are significantly different at p ≤ 0.05 applying the fisher's lsd test. here, T1=wheat straw (100%), T2 = wheat straw (90%) + vermicompost (10%), T3 = wheat straw (75%) + vermicompost (25%), T4 = wheat straw (50%) + vermicompost (50%), T5 = wheat straw (25%) + vermicompost (75%), T6 = rice straw (100%), T7 = rice straw (75%) + vermicompost (25%), T8 = rice straw (90%) + vermicompost (10%), T9 = rice straw (25%) + vermicompost (75%), T10 = rice straw (50%) + vermicompost (50%), T11 = vermicompost (100%)*

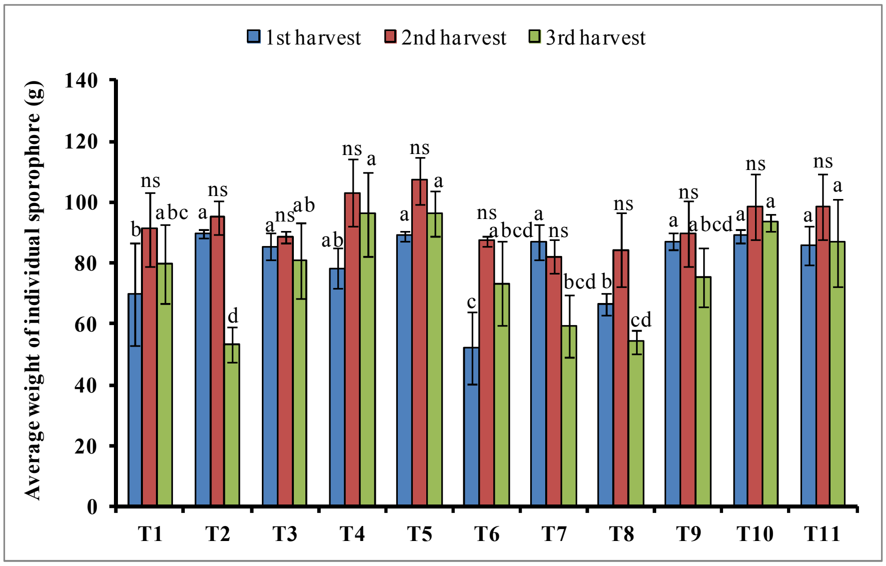

Fig. 1 Effect of vermicompost-enriched substrates on average weight of individual sporophore of milky mushroom

Means (±SD) were calculated from three replicates for each treatment. Values with different letters are significantly different at P ≤ 0.05 applying the Fisher's LSD test. Here, T1= wheat straw (100%), T2 = wheat straw (90%) + vermicompost (10%), T3 = wheat straw (75%) + vermicompost (25%), T4 = wheat straw (50%) + vermicompost (50%), T5 = wheat straw (25%) + vermicompost (75%), T6 = rice straw (100%), T7 = rice straw (75%) + vermicompost (25%), T8 = rice straw (90%) + vermicompost (10%), T9 = rice straw (25%) + vermicompost (75%), T10 = rice straw (50%) + vermicompost (50%), T11 = vermicompost (100%)

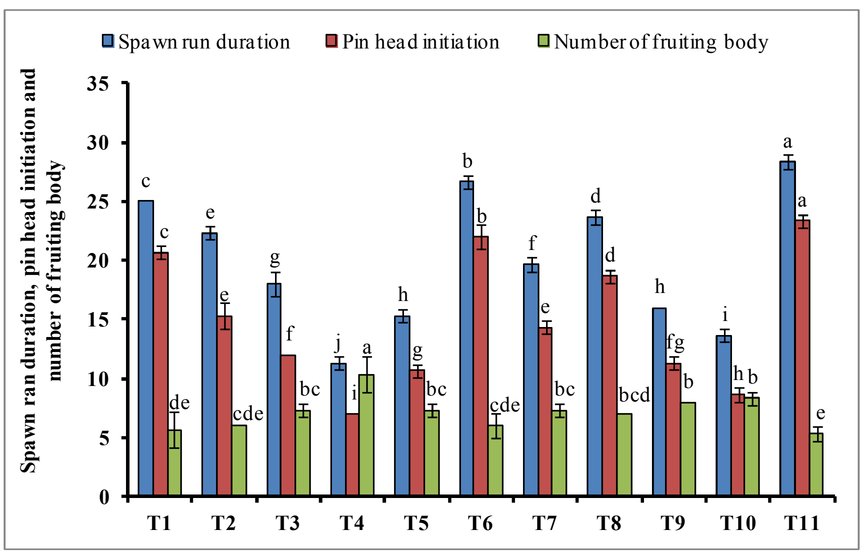

Fig. 2. Effect of vermicompost-enriched substrates on Spawn run, pin head initiation and number of total fruiting body per packet of milky mushroom

Means (±SD) were calculated from three replicates for each treatment. Values with different letters are significantly different at P ≤ 0.05 applying the Fisher's LSD test. Here, T1= wheat straw (100%), T2 = wheat straw (90%) + vermicompost (10%), T3 = wheat straw (75%) + vermicompost (25%), T4 = wheat straw (50%) + vermicompost (50%), T5 = wheat straw (25%) + vermicompost (75%), T6 = rice straw (100%), T7 = rice straw (75%) + vermicompost (25%), T8 = rice straw (90%) + vermicompost (10%), T9 = rice straw (25%) + vermicompost (75%), T10 = rice straw (50%) + vermicompost (50%), T11 = vermicompost (100%)

supplemented with different doses of vermicompost compared with wheat straw alone, similarly vermicompost addition with rice straw helped to increase total number of fruiting body ranged between 17% - 39% compared to unsupplemented rice straw.

3.5 Yield and Bioefficiency of Milky Mushroom

The yield of *C. indica* varied markedly from 362 g to 897 g (Fig 3) with respect to different doses (0%, 10%, 25%, 50% and 75%) of vermicompost supplementation with different substrates (rice and wheat straw). Vermicompost addition with 10%, 25%, 50% and 75% levels gave 23%, 54%, 121% and 73% increase in fresh yield of *C. indica* compared to wheat straw alone and 31% , 63%, 112% and 87% increase compared to rice straw alone. The biological efficiency of *C. indica* also did exhibit significant difference ranged between 65- 160 % (Fig. 3) among different levels of vermicompost supplementation with rice and wheat straw substrates.

Vermicompost supplementation in rice straw and wheat straw showed good agronomical performance in the cultivation of C. indica. The delayed-released nutrients of vermicompost might be responsible to limit the availability of proteins of substrates for competitors moulds and then the mushroom mycelium could take the gradually accessible nutritional content when it (mushroom) became dominant within the substrates [11,12].

The addition of vermicompost with rice and wheat substrates improved the average diameter of pelius, thickness of pelius, diameter of stipe and length of stipe relative to the unsupplemented substrate. It was possible to find some correlations that may be useful for the use of vermicompost as a substrate supplement to produce *C. indica*. The most important elements that were required for better yield of mushroom was C/N ratio [13] and the majority of supplements sold commercially are currently based on nitrogen rich compounds, though it is unclear whether the use of low-protein supplements based on carbon-rich sources such as cellulose and hemicellulose components improves the performance of the mushroom equally or even more than nitrogen addition. Chemical fertilizer works quicker than compost in releasing nutrients so the nutrients get depleted easily. The organic nitrogen from vermicompost is released and mineralized faster from the excreted humas by worms, so the net overall efficacy of nitrogen (N) is considerably higher in vermicompost compared to chemical fertilizer [14]. Mushrooms require two main macronuitrients C and N for structural and energy requirements. Furthermore, P, K and Mg are also considered important macronutrients for mushrooms and for doing some diverse functions trace elements like Fe, Se, Zn, Mn, Cu and Mo appear to be needed [15]. Vermicompost is at least 4 times more nutritive in comparison with cattle dung compost [16] and on a weight basis higher N availability was found in vermicompost than the conventional compost [17]. With the

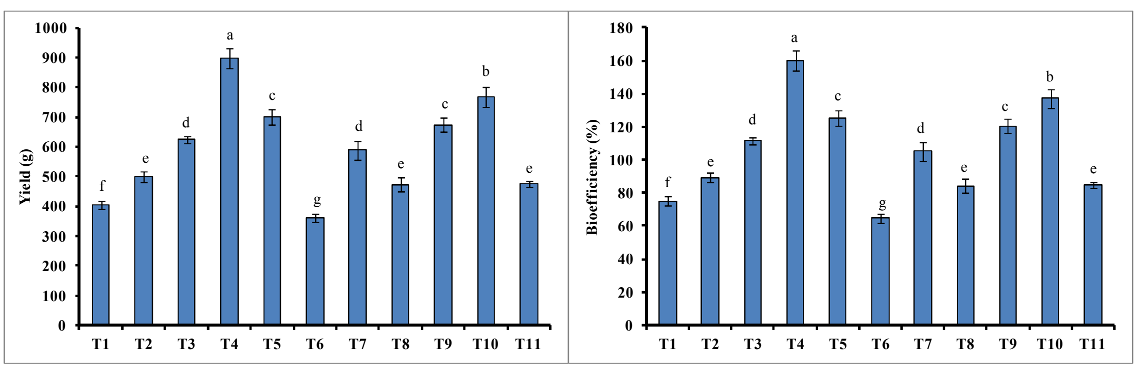

Fig. 3. Yield and Biological efficiency of *Calocybeindica*under different treatments

Means (±SD) were calculated from three replicates for each treatment. Values with different letters are significantly different at P ≤ 0.05 applying the Fisher's LSD test. Here, T1= wheat straw (100%), T2 = wheat straw (90%) + vermicompost (10%), T3 = wheat straw (75%) + vermicompost (25%), T4 = wheat straw (50%) + vermicompost (50%), T5 = wheat straw (25%) + vermicompost (75%), T6 = rice straw (100%), T7 = rice straw (75%) + vermicompost (25%), T8 = rice straw (90%) + vermicompost (10%), T9 = rice straw (25%) + vermicompost (75%), T10 = rice straw (50%) + vermicompost (50%), T11 = vermicompost (100%)

addition of vermicompost to soil the availability of several other plant nutrients (P, K, S and Mg) were considerably increased than conventional compost [18,19].

Vermicompost supplementation accelerated the growth of mycelium, which resulted shorter duration of spawn run and quicker pin head initiation in both wheat and rice straw. Similarly, total number of fruiting body also increased in wheat and rice straw after supplemented of different doses of vermicompost. The average weight of individual sporophore of *C. indica* showed insignificant difference among treatments. Though to some extent supplementation increased the weight in wheat straw and rice straw but some treatments of supplementation showed decrease in sporophore weight which was possible to find some correlations with increasing number of fruiting body. The yield of *C.indica* varied markedly with respect to different doses of vermicompost supplementation with different substrates (rice and wheat straw). Vermicompost addition increased the fresh yield of *C. indica* compared to wheat and rice straw alone. The biological efficiency of *C. indica* also did exhibit significant difference among different levels of vermicompost supplementation with rice and wheat straw substrates.

The mycelium growth has been found to be stimulated and the fructification, yield as well as biological efficiency have been found to be promoted due to the reason of potential mushroom growth promoting (MGP) fungi and bacteria [20,21]. There has been described the increasing mycelial growth of mushrooms from different bioinoculants including bacteria from the genera Azotobacter, Bacillus, Paenibacillus and Pseudomonas while antagonism has been found against competitive molds reported as candidates for the design of alternative nutritional supplements/biofertilizers [22,23 and 24]. So, vermicompost acts similarly in our experiment because of its richness in microbial populations and diversity, particularly fungi, bacteria and actinomycetes [25,26]. Bacterial count of 32 million per gram in fresh vermicast in comparison with 6-9 million per gram in the surrounding soil have been reported by reference [27,28]. An increase of 90% in respiration rate in fresh vermicast indicating corresponding increase in the microbial population was found by reference [29]. Some researcher reported that the total bacterial count was more than 1010 per gram of vermicompost [30]. It included Actinomycetes, Azotobacter, Rhizobium, Nitrobacter and phosphate solubilizing bacteria which ranged from 102-106 per g of vermicompost. Comparing with the conventional thermophilic composts, vermicomposts possess outstanding chemical and biological properties with plant growth regulators (lacking in other composts) and significantly larger and diverse microbial populations [31,32].

To degrade the lignocellulosic substrates, mushrooms produce a number of enzymes including lignin-degrading enzymes (laccases, lignin peroxidases, manganese peroxidases, arylalcohol oxidase, aryl-alcohol dehydrogenases or quinonereductases), and hemicellulose and cellulose-degrading enzymes (xylanase, cellulases or cellobiose dehydrogenase), [33, 34 and 35].

The reason for low biological efficiency on vermicompost may be attributed to unavailability of necessary ligno-cellulosic compounds in required amounts for fruit body formation. Vermicompost addition with equal amount of wheat straw was the best suitable substrate in respect of spawn run period, pin head formation time, average weight of fruit body and biological efficiency. Proportionate amounts of lignin, cellulose, hemicellulose and required macro and micro nutrients in wheat and rice straw supplemented with vermicompost might have played the important role in performance of the mushroom under study.

4. CONCLUSION

We worked different doses of vermicompost as a supplement with two different substrates (rice straw and wheat straw) but equal proportion of vermicompost with wheat straw gave highest yield and biological efficiency. Besides, the addition of vermicompost in equal amount with rice straw also showed the second highest increase in the yield and biological efficiency compared with nonsupplemented one. Application of vermicompost to substrates with lower levels would provide an even better yield, without adversely affecting the bioefficiency and yield. So, if we enrich our substrate to cultivate milky white mushroom it may give upto 112% higher yield. In future, to achieve successful supplementation, mushroom grower may consider supplementing the substrate by adding vermicompost because it helps to increase the sporophore size, number, yield and biological efficiency. There has a great scope of nutrient analysis of substrates and sporophores which will help to understand the nature of nutrient release by the substrates and uptake by the fruiting body.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

ACKNOWLEDGEMENTS

We acknowledge Professor Dr. Mirza Hasanuzzaman, Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Bangladesh for his critical reviewing the manuscripts, Dr. Akhter Jahan Kakon, Upazila Agriculture Officer, Mushroom Development Institute, Bangladesh and Mahbuba Jamil, Mushroom Development Officer, Mushroom Development Institute, Bangladesh for their kind cooperation during data collection.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/61854