



RESEARCH ARTICLE

Strategic Approaches for Outdoor Cultivation of Paddy Straw Mushroom (*Volvariella volvacea*) as Intercrop Under different Cropping Systems

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ABSTRACT

The present study aimed to select potential strain of *Volvariella volvacea* suitable for outdoor cultivation in different cropping systems like Banana, Maize, Coconut, Coconut+Banana where such suitable microclimate prevails. Among the different strains of *V.volvacea* tested, the strain Vv-19-06 obtained from Directorate of Mushroom Research, Solan, performed considerably superior with higher bioefficiency of 17.44 and sturdy sporophores at egg stage and storage life of 1.1 days under refrigerated condition. Moreover, the morphogenesis of button stage to matured mushrooms were extended up to 1.8 days and the opened mushroom were retained on the bed for another 1.6 days, which is an added advantage. Cultivation of paddy straw mushroom as intercrop in Banana, Maize, Banana+coconut and Coconut cropping systems proved successful with spawn running completion ranging from 8 to 10.3 days, pinhead formation ranging from 9.3 to 11.6 days and harvestable button/egg stage appeared ranging from 11 to 12.6 days. The bioefficiency was comparatively better in all the cropping systems, which ranged from 19.4 to 20.6 %, with a total cropping cycle of 20.5 to 22 days. The indoor cropping system, which requires additional cost for infrastructure, also recorded bioefficiency of 21.3 in a cropping cycle of 17 days. In all the cropping systems tested, the B:C ratio worked out to be 1:2.3 to 1:2.5 as in indoor cropping system proving that paddy straw mushroom could be promoted for the outdoor system in Maize, Banana, Banana +coconut, Coconut cropping systems as intercrop as it fetches additional income to rice-growing farmers.

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INTRODUCTION

The Paddy straw mushroom (*Volvariella volvacea*) or Chinese mushroom, well known for its pleasant flavor and taste, ranks sixth among cultivated edible mushrooms and contributes to about 5 to 6 % of world mushroom production (Ahlawat *et al.*, 2011). Another significant feature of this mushroom is its early harvest on 10th day itself, with a shorter cropping cycle of 20 to 22 days compared to any other commercially cultivated mushrooms. Though lot of attempts have been exploited in India (Su and Seth 1940, Thomas *et al.*, 1943; Kandasamy and Ramasamy, 1975, Pani and Naik, 1998; Sangeetha, 2002, Ahlawat and Tewari, 2007; Thiribhuvanamala *et al.*, 2012), commercial cultivation of *V.volvacea* is still in infant stage because of weak colonization of the substrate by mycelium due to poor ligninolytic enzyme secretory system that ultimately leads to poor yields.

Perusal of literature shows that China is leading in paddy straw mushroom with the production of about 60,00,000 tonnes of mushroom (Wang *et al.*, 2017) where successful cultivation by large number of growers is possible both as indoor and outdoor crop. However, in India, only Odisha state leads in paddy straw mushroom production with an annual production of 8007 tonnes as plenty paddy straw is available coupled with cheap labor and low investment as they cultivate outdoors. Chattisgarh also has started the commercial cultivation of paddy straw mushrooms by small and marginal farmers. This mushroom prefers paddy straw as the best substrate to give optimum yield through perusal of literature shows lot of substrates viz., Banana waste (Zikriyani *et al.*, 2018) cotton waste and oil palm bunch waste (Thiribhuvanamala *et al.*, 2012) prove promising when substituted along with paddy straw with a bioefficiency of 19.2 to 21.9 per cent.

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This mushroom prefers an optimum temperature of 32 to 40°C with a relative humidity of 75 to 85 % to get stable yields and so mainly cultivated indoors. Due to poor yields, the indoor cultivation of paddy straw mushroom *V.volvacea* involves a high cost of production and net returns are very low.

Moreover, in Tamil Nadu rice being the major crop, plenty of straw is available even after feeding the cattle is left unused and can be converted to produce paddy straw mushroom especially in delta and coastal areas. In this context, the present study was proposed with an aim to promote commercial cultivation of paddy straw mushroom in the cropping systems like Maize, Banana and Coconut as intercrop (at particular stage of the crop) where such cropping requirements favorable for paddy straw mushroom cultivation are available naturally. Apart from this, the study is focused on the identification and selection of a suitable strain of *V.volvacea* that can provide maximum yield with quality attributes of sturdy egg-shaped buttons that would have more retention period on beds and could tolerate the fluctuating environmental conditions during the cropping period. Hence, this study would offer scope for the commercial cultivation of paddy straw mushrooms with low investment cost and more returns to the farmers.

MATERIALS AND METHODS:

Identification of high yielding *Volvariella* strain

An experiment was conducted to identify high yielding strain of *V.volvacea* with good sporophore characters so as to take forward the strain for outdoor cultivation. Five different strains of *Volvariella volvacea*, Vv-19-01 to Vv-19-06 were tested in comparison with TNAU strain of *V.volvacea* (PS1 collected from Repository culture collection centre of TNAU) for yield performance in sunken blue polyhouses at TNAU where a temperature of 32 to 36°C and relative humidity of 80-85 % was maintained throughout the cropping period. Paddy straw was soaked in water for 6 hours and pasteurized by steaming for 1 hour and each bed was prepared in bundle method with 3 bundles x 4 layers with 1 bundle opened at the top with bed size of 1.5 x1.5 x1.5 cu.ft as per the Technical Programme of AICRP Mushroom,2020 using 300 g paddy straw per bundle with a total of 4 kg substrate per bed. Spawn was prepared using chopped paddy straw bits mixed with 2% horse gram powder and autoclaved at 15 lbs (121°C) for 30 minutes and inoculated with respective *V.volvacea* cultures. After 15 days when spawn turned to chocolate brown with the formation of chlamydospores, it was used to prepare beds @ 2% spawning. The Days for Spawn run (DFSR), Days for Pinhead Formation (DFPF), Days for First Harvest (DFFH), Number of fruiting

bodies and Average weight of single sporophore and Biological efficiency (%) were recorded (Yang et al., 2013) .

Biological efficiency (BE) is calculated in % as

$$\frac{\text{Total weight (kg) of harvested mushrooms}}{\text{Total weight (kg) of substrate used}} \times 100$$

Testing outdoor cultivation of *V.volvacea* in different cropping systems

A study was attempted to utilize the existing natural microclimate in cropping systems suitable for cultivation of paddy straw mushroom at 32-40°C and relative humidity of 80 to 85% so as to reduce the cost of production. A trial for the cultivation of paddy straw mushroom, *V.volvacea* was performed during the month of October 2020 under different cropping systems viz., Banana, Maize, Coconut, Coconut + Banana cropping systems. Paddy straw mushroom spawn was prepared in paddy substrate (as mentioned above) and bundle method beds (with 3 bundles x 4 layers with 1 bundle opened at the top with bed size of 1.5 x1.5 x1.5 cu.ft. using 500 g paddy straw per bundle with a total of 6 kg substrate per bed). Spawn prepared in paddy straw as substrate with good chlamydospore formation was spawned at the rate of 2% in the beds. For this purpose, paddy straws were soaked in cold water with 3 % lime (commercial grade Calcium hydroxide) for 6 hours, drained excess water until 60% moisture and used to prepare bundle method beds as mentioned earlier.

For the cultivation of *V.volvacea* in the Banana cropping system, fifteen bundle method beds as prepared above were laid in the interspaces of Banana plants (cv.Grand Naine) at the University orchard and covered with polythene sheet for 5 days. Similarly, for the cultivation of *V.volvacea* in Coconut cropping system, fifteen bundle method beds were prepared as above and laid in the interspaces of coconut trees (three rows) at the university Coconut farm of the university and covered with thin polythene sheets up to 6 days to maintain warmth and humidity. In the Maize cropping system, fifteen bundle method beds were prepared as above and laid in the interspaces of Maize crop (60 x 30 cm) (three rows) at university Eastern block farm and covered with thin transparent, recyclable polythene sheet for 5 days. For cultivation of *V.volvacea* in Coconut + Banana cropping system, fifteen bundle method beds were prepared as above and laid in the interspaces of Coconut + Banana cropping system where Coconut (10 years crop) was cultivated with the spacing of 7x7 m spacing and Banana crop (7 months) was cultivated in the interspaces of coconut (three rows) in farmers field at Ajanur village of

Coimbatore and covered with thin transparent, recyclable polythene sheet for 5 days

Beds were sprinkled with water twice for 15 days from 6th day onwards after opening of the polythene sheets. In all the conditions, throughout the cropping period, daily bed temperature and relative humidity around the beds and the environmental factors with respect to morning and evening temperature and relative humidity were recorded using digital hygrothermometer. The DFSR, DFPF, DFFH, Number of fruiting bodies and average weight of single sporophore were recorded as above. The different stages of mushrooms include pinhead stage (primordia formation), button/ egg stage, matured/

bell-shaped mushrooms. Biological efficiency (%) and B:C ratio were calculated. For comparison, during the same period, fifteen bundle method beds were prepared as above and placed in blue polyhouses where temperature of 34 to 37 °C and RH of 80 to 85 % was maintained. Beds were sprinkled with water twice for 15 days from 6th day onwards. In all the conditions, throughout the cropping period, daily bed temperature and relative humidity around the beds and the environmental factors inside the polyhouse with respect to morning and evening temperature and relative humidity were recorded using digital hygrothermometer. Yield parameters were recorded as described above.

Table 1. Bioefficiency and yield performance of different *Volvariella* strains

Strains	DFSR	DFPF	DFFH at egg stage	Sturdiness of egg stage mushroom	Days taken from egg stage to bell stage	Av. no. of fruiting bodies/bed	Average weight of mushrooms (g)	Retention of bell shaped mushrooms on beds (days)	Average yield /bed (Kg)	Bioefficiency (%)
Vv-19-01	8.9	9.9	11.1	+	1.2	27.7	30.28	0.6	0.839	12.92
Vv-19-02	12.4	14.5	15.2	+	0.7	25.3	23.90	0.7	0.605	9.32
Vv-19-03	8.5	10.4	11.2	++	0.8	27.8	36.22	1.0	1.009	15.52
Vv-19-04	12.1	13.9	14.5	+	0.6	25.2	24.78	0.6	0.625	9.60
Vv-19-05	13.1	14.8	15.3	+	0.5	25.7	24.44	0.7	0.629	9.64
Vv-19-06	8.7	10.4	12.2	+++	1.8	31.5	35.98	1.6	1.134	17.44
PS1 (TNAU)	8.0	10.0	11.2	+	0.8	32.0	33.08	0.7	1.056	16.20
SEd	0.708	0.806	1.504			2.36	1.20	0.02	0.084	
CD (0.05%)	1.477	1.682	3.138			4.93	2.50	0.04	0.175	

Sturdiness of buttons : +: light ++ : medium +++ : thick

Statistical Analysis

Mean differences of the treatment were evaluated with ANOVA using Duncan's Multiple Range-Test at 5% significance (Gomez and Gomez, 1984). All

the data were statistically analyzed with IRRISTAT (version. 3/93, Biometrics unit, International Rice Research Institute) and consequently interpreted.

Table 2. Performance trial on the out door cultivation of *V. volvacea* under different cropping systems

Treatments	Cropping systems /house	Environmental conditions		Bed conditions		DFSR (Days)	DFPF (Days)	DFFH (Days)		Fruiting body (Average)		Av. yield /bed (kg)	TCP (Days)	BE (%)	B:C
		Temp. °C	RH (%)	Temp. °C	RH (%)			Egg stage	Bell shape	Weight (g)	Number (No.)				
T ₁	Banana	30.0	62.5	39.3	86.5	8.0	9.3	11.0	13.0	27.8	29.7	0.826	21.0	20.6	1:2.5
T ₂	Maize	29.0	62.4	37.0	84.0	9.0	10.3	11.3	12.6	26.8	29.0	0.777	20.5	19.4	1:2.4
T ₃	Coconut	30.3	60.0	36.5	83.5	10.3	11.6	12.6	13.5	25.8	29.5	0.761	22.0	19.0	1:2.3
T ₄	Coconut + Banana	28.0	62.0	37.0	84.5	9.3	10.6	12.0	13.5	26.8	29.3	0.785	22.0	19.6	1:2.4
T ₅	Indoor (polyhouse)	34.0	82.7	37.3	83.7	8.0	9.5	10.5	12.0	30.1	28.3	0.851	17.0	21.3	1:2.5
	SEd					0.25	0.28	0.24	0.18	0.32	0.26	13.3			
	CD(0.05%)					0.50	0.56	0.48	0.37	0.64	0.53	26.7			

RESULTS AND DISCUSSION

Out of the seven strains of *Volvariella volvacea* tested, the results showed that strain Vv-19-06 recorded maximum bioefficiency of 17.44 % (1.134 kg/bed) followed by Vv-19-03 with 15.5 % bioefficiency (1.009 kg/bed) in 6 kg paddy straw/bed. The average number of fruiting bodies were maximum in Vv-19-06, Vv-19-03 and Vv-19-01 (31.5, 27.8 and 27.7 numbers) (Table 1). The spawn run completed was earlier and on par with each other in Vv-19-03, Vv-19-06, Vv-19-01 and PS1 ranging from 8 to 8.9 days compared to other strains Vv-19-02, Vv-19-04 and Vv-19-05, which took longer days for spawn run completion (12 to 13 days). The

pinheads/primordia emerged early in Vv-19-01 on 9th day followed by PS1, Vv-19-03 and Vv-19-06 when compared to other strains (13.9 to 14.5 days). Similarly, the strains Vv-19-01, Vv-19-03 and PS1 produced sporophores at egg/button stage ready for harvest within 11 to 11.5 days whereas Vv-19-06 took 12 days; however, they were on par with each other. However, the average fruit body weight was maximum in Vv-19-06 and Vv-19-03 and PS1 (35.98g, 36.22 g, 33.08g, respectively). The average number of fruiting bodies/bed was maximum in PS1 (32 numbers) and Vv-19-06 (31.5 numbers). Significantly superior biological efficiency of 17.44 % in Vv-19-06 followed by Ps1 (16.2 %) was recorded.



Figure 1. Selected strain Vv-19-06 of Paddy straw mushroom, *V. volvacea*

Interestingly, the sturdiness of egg stage mushrooms were thick in Vv-19-06 compared to PS1 and other strains, followed by Vv-19-03 with medium sturdiness (Fig.1). Sturdiness is an important attribute in the case of Vv-19-06 as noticed by the increased time taken by 1.8 days to open from egg to bell /umbrella shaped sporophores with increased retention of another 1.6 days in the beds. This increased time taken for morphogenesis from egg to bell shape added with more retention time on the beds offers advantage for quality mushrooms compared to other strains where morphogenesis happened quickly and led to over matured sporophores within a short time. Moreover, the egg stage of Vv-19-06 had higher

sturdiness due to the thick volva that covered the egg stage sporophores. The sporophores of strain Vv-19-06 that opened after morphogenesis had thick pileus of 0.4 cm that offered more shelf life of 1 day under room temperature (newspaper bags) compared to other strains (0.2 to 0.37 cm) with shelf life of only 6 hours (data not shown). The strain Vv-19-06 was found highly suitable for commercial cultivation and used for testing its suitability under outdoor cultivation trials.

Though there are about 19 recorded species of *Vovariella* in India, only three species have been explored for cultivation viz., *V. volvacea* (Bull ex Fr.) Sing., *V. esculenta* (Mass) Sing., *V. diplasia* (Berk and Br.) Sing. and among them, *V. volvacea* is

preferred owing to its quick growth and significant yield compared to others. Selection of strain is the foremost factor to be considered for cultivation of paddy straw mushroom as those strains proving better in indoor cultivation fails to perform in outdoor conditions due to fluctuating temperature and

relative humidity. In our study, the *V.volvacea* strain Vv-19-06 produced good chlamydo-spore formation in spawn and produced sporophores with sturdy buttons and prolonged morphogenesis without deterioration during the cropping period that offers scope for outdoor cultivation.

Fig. 2. Outdoor cultivation of *V.volvacea* under different cropping systems

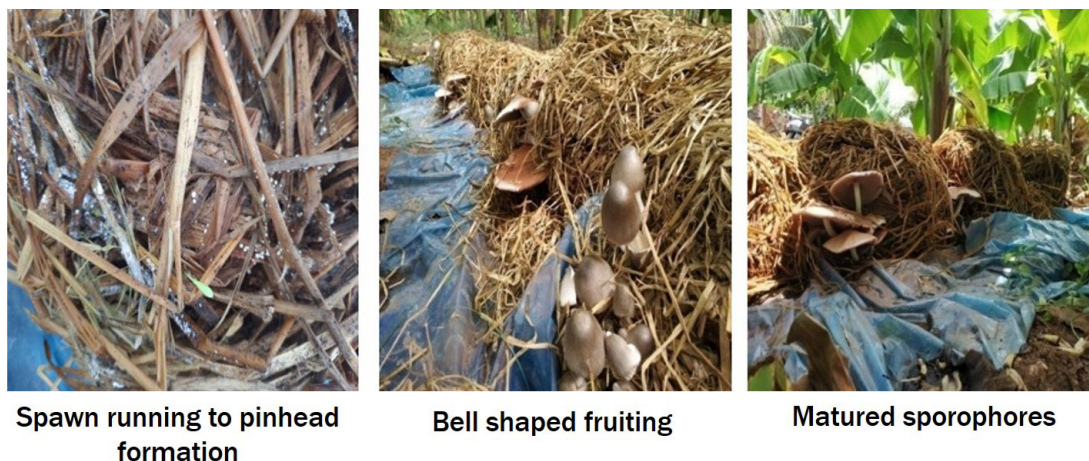


Figure 2a. Production of *V.volvacea* in Banana cropping system

The idea behind the outdoor cultivation of paddy straw mushrooms is to effectively utilize the prevailing natural microclimate in the cropping system to accomplish low investment and get good returns. The cultivation of *V.volvacea* was attempted during the second week of September to first week of October 2020.in different cropping systems and compared with the indoor cultivation system and the results are presented in Table 2 and Fig.2

The results revealed that in the banana cropping system (T1) the strain Vv-19-06 showed that spawn running was completed on 8th day and pinheads appeared on 9.3 days and egg stage mushrooms developed on 11th day (Fig. 2a.). The matured fruiting bodies at bell stage were observed on 13th day. The paddy straw bundle beds were recorded an average bed temperature of 39.3°C and relative

humidity of 86.5% throughout the cropping period and the environmental conditions recorded average temperature of 30°C and 62.5 % relative humidity. One interesting observation is that the bell/ umbrella stage mushrooms were retained on the bed for another 11 hours, which might be due to the high humidity prevailing in the banana cropping system. So there is enough time of 2 days from egg stage to bell /umbrella-shaped stage, which is advantageous to the farmer to harvest mushrooms depending upon demand as in case of oyster and milky mushroom. On average 29.7 fruiting bodies with an average weight of 27.8 g per sporophore was obtained with biological efficiency (BE) of 20.6 % (0.826 kg/bed) which accounted to C:B ratio of 1: 2.5 (Fig.1). The total cropping cycle (TCP) was observed as 21 days in three harvests.

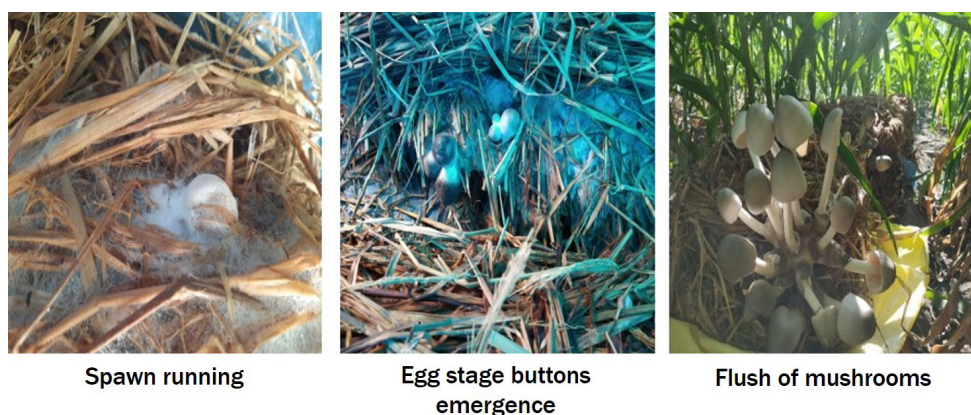


Figure 2b. Production of *V.volvacea* in Maize cropping system

Similarly, in the Maize cropping system (T2), the spawn running of strain Vv-19-06 as completed on 9th day and pinheads appeared on 10.3 days and egg stage mushrooms developed on 11.3days and bell-shaped mushrooms were harvested up to 12.6 days and were able to retain on the bed for another 9 hours with a total cropping cycle (TCP) of 20.5 days (Fig.2b). On an average 29.0 fruiting bodies with an average weight of 26.8 g was obtained with biological efficiency (BE) of 19.4 % (0.777 kg/bed),accounting to C:B ratio 1:2.4 in three harvests. An average bed temperature of 37°C and RH of 84.0 % and environmental conditions of Maize field recorded an average temperature of 29°C and RH of 62.4 % was recorded during the cropping period.

Also, in coconut cropping system (T3), the spawn running of strain Vv-19-06 was completed on 10.3 day and pinheads appeared on 11.6 days and egg stage mushrooms developed on 12.6 days and bell-shaped mushrooms were harvested up to 13.5 days and were able to retain on the bed for another 7 hours without any deterioration (Fig.2c). On an average 29.5 fruiting bodies with an average

weight of 25.8 g per sporophore was obtained with biological efficiency (BE) of 19.0 % (0.761 kg/bed) and total cropping cycle (TCP) of 22 days with C:B ratio accounting to 1:2.3 in three harvests. The bed average temperature of 36.5°C and relative humidity of 83.5 % and environmental conditions in the coconut field recorded an average temperature of 30.3°C and 60 % RH during the cropping period.

In Coconut+Banana cropping system (T4), the strain Vv-19-06 showed that spawn running was completed on 9.3 day and pinheads appeared on 10.6 days and egg stage mushrooms developed on 12th day and bell shaped mushrooms were harvested up to 13.5 days and were able to retain on the bed for another 8 hours with a total cropping cycle (TCP) of 22 days (Fig.2d.). On an average 29.3 fruiting bodies with an average weight of 26.8 g was obtained with biological efficiency (BE)of 20.3 % (0.785 kg/bed),accounting to C:B ratio accounting to 1:2.5 in three harvests. An average bed temperature of 37°C and RH of 84.5 % and field environmental conditions with average temperature of 28 °C and 62% RH was recorded during the cropping period.

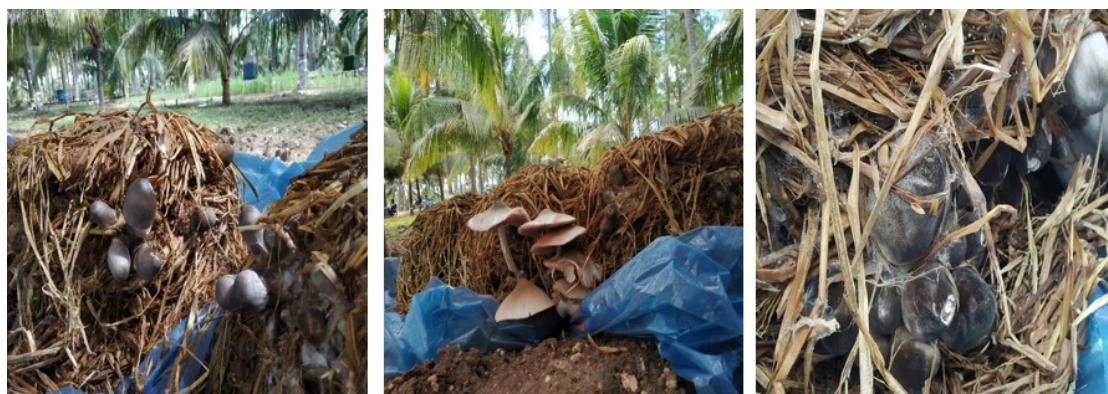


Figure 2c. Production of *V. volvacea* in Coconut cropping system

The indoor cultivation (T5) of *V. volvacea* strain Vv-19-06 in polyhouses the spawn running was completed on 8th day and pinheads appeared on 9.5 days and egg stage mushrooms developed on 10.5 days and bell-shaped mushrooms were harvested up to 12 days and were able to retain on the bed for another 10 hours without any deterioration. On an average 28.3 fruiting bodies with an average weight of 30.1 g per sporophore was obtained with biological efficiency (BE) of 21.3 % (0.851kg/bed) and total cropping cycle (TCP) of 17 days with C:B ratio accounting to 1:2.5 in three harvests. The bed average temperature of 37.3°C and relative humidity of 83.7 % and environmental conditions inside polyhouse recorded average temperature of 34°C and 82.7 % RH during the cropping period.

For maximizing yield in paddy straw mushroom, suitable strain selection is important that grows

quickly and colonizes the substrate, thereby leading to the production of pinheads under favorable environmental conditions. However, the tropical plains of India offer suitable climatic conditions with a prolonged growing season from February to October, providing an ideal temperature for the cultivation of *V. volvacea*. For year-round cultivation of paddy straw mushrooms, the requirement of additional cost for the erection of poly houses or shade nets is the disadvantage of indoor cultivation method (Mahapatra *et al.*, 2020), which involves high investment and low returns. So as in our study the microclimate available in cropping systems like Maize, Banana and coconut is found to be quite suitable with 35 to 37° C with relative humidity of 80-85% throughout the cropping period. Earlier outdoor cultivation of paddy straw mushroom (*Volvariella volvacea*) was experimented in maize-based cropping system (Krishnamoorthy *et al.*, 2005) and

in the banana field in Orissa (Pani and Naik ,1998). Thuc *et al.*, (2020) has attempted the outdoor cultivation of paddy straw mushroom for poverty alleviation in Vietnam, Philippines and Thailand. However, few researchers pointed out that outdoor system of cultivation led to lower yields compared to indoor cultivation in polyhouses, bamboo and thatched roofs (Rajapakse,2011; Thakur and Yadav,2006) due to fluctuation in temperature and humidity. But in our study, the net returns were on par with the indoor cultivation since there are not many alternations in climatic conditions within the cropping system except for the shorter cropping period earlier by three days in the indoor system. There were no differences noticed in the quality of mushrooms with respect to number of harvested mushrooms and their weight. Moreover, as the

farmer utilizes the labor taking care of the cropping system, investment is less. Among the cropping systems, Banana and Coconut+ Banana followed by Maize cropping system proved successful for commercial cultivation of paddy straw mushroom provided good quality spawn must be available. It is inferred that in Maize cropping system (45 days to 75 days of maize crop) and in Banana cropping systems (7th to 9th-month banana crop stage) and in coconut+ Banana cropping system (7th to 9th-month banana crop stage), about 4 crops of paddy straw mushroom and in coconut cropping system about 10 to 12 crops of paddy straw mushroom can be planned which will provide additional income to farmers. Also, the spent mushroom substrate after harvest can be converted into biomanure and incorporated into the field.



Figure 2d. Production of *V.volvacea* in Coconut + Banana cropping system

CONCLUSION

This study offers scope and attracts the farming community for taking up cultivation of paddy straw mushroom as an intercrop in Banana, Maize, Coconut+ Banana and Coconut cropping systems without any additional preliminary investment and provides good net returns. No other vegetable other than *V.volvacea* has shorter crop duration and certainly, promotion of commercial cultivation by a large group of farmers not only provides additional income but also introduces another delicious edible mushroom to the consumers.

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