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***Research Paper***

# Seasonal variation of paddy straw mushroom performance under different microclimate environment


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**ABSTRACT**

Maize is an important base crop in intensive irrigated cereal based cropping system because of its wider climatic acclimatization. In contrast, a certain microclimate is needed for commercial mushroom production. Favourable microclimatic condition that prevails in maize field created a greater opportunity to grow the warm loving Paddy Straw Mushroom "*Volvariella volvacea*" as intercrop. In this context, a comparative study was taken up at Tamil Nadu Agricultural University to determine the performance of paddy straw mushroom as intercrop under different microclimate created in irrigated maize and polyhouse during summer and *kharif* 2022. Study concluded that the microclimate variables during *kharif* season was more favourable for obtaining higher straw mushroom yield as maize intercrop, but the summer season was also an economically viable one. The study found that the most ideal limits of microclimate variables such as morning and afternoon temperature, morning and afternoon RH for paddy straw mushroom was 26 to 29°C, 29 to 33°C, 80 to 98 per cent and 66 to 88 per cent, respectively. The polyhouse showed its superiority in providing controlled favourable microclimate for paddy straw mushroom than the fluctuating microclimate under maize canopy, however the higher infrastructural investment in polyhouse farming is not affordable for the small and marginal farmers. The microclimate prevailed in between maize rows could support paddy straw mushroom intercropping as a viable system, which had Land Equivalent Ratio of more than 1.6 and double the time of Crop Equivalent Yield when compare to sole cropped maize.



***Keywords***: Paddy straw mushroom; *Volvariella volvacea*; microclimate; polyhouse; maize intercrop.


Maize (*Zea mays* L.), the queen of cereals is acclimatizing to wide range of climatic conditions. The wide row spacing of maize can be effectively utilized for additional returns through intercropping. Spatial and temporal diversification in maize cropping systems provides opportunities to reduce vulnerability through ecological intensification and produce more diversified food products (Renwick *et al.,* 2020). In sub-tropical and underdeveloped nations, intercropping has always been the most popular method of cropping system, which boost total productivity per unit area and time.

Intercropping provides various benefits, such as protection against crop failure (Rusinamhodzi *et al.,* 2012), enhanced productivity, production stability, product maximization, soil fertility and pest control, and additional profits from companion crops (Khanal *et al.,* 2021). The most notable advantage of intercropping over monocropping is increased productivity due to high resource use efficiency. Land equivalent ratio larger than one was found in the various intercropping systems tested using maize as the base crop, demonstrating that intercropping was preferable to monocropping.

Paddy straw mushroom is also referred to as "warm mushroom" because to its relative ability to thrive at higher temperatures than other edible mushrooms. Temperature and relative humidity were regarded as key meteorological variables for growing straw mushroom and hence it is grown in a controlled environment (Reyes, 2000). The optimal conditions for the paddy straw mushroom are 30-35°C and 80-90% relative humidity, respectively (Ahlawat and Arora, 2016). Production of paddy straw mushroom is a sustainable method for adding value to paddy straw and decreasing environmental pollution by preventing the burning of paddy straw in the field (Thuc *et al.,* 2020). It is a fast growing mushroom and the entire harvest cycle may be completed in 20-25 days under


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ideal growth conditions and another noteworthy feature is that it starts yielding mushrooms on the 10th day post spawning (Thiribhuvanamala *et al.,* 2021).

There were differences of opinion between the earlier studies and crop growth in controlled environments like poly houses. It was noted in a polyhouse trial of bell pepper production that slight variation in microclimate condition of the polyhouse at critical stage of the crop growth would resulted in significant variation in crop growth and fruit setting (Brar *et al*., 2006). While comparing different controlled environment structures, Shukla *et al.,* (2016) opined that the resource poor farmers need low-tech protected structures to cultivate high value crops for enhanced economic security. Samanta and Hazra (2019) reported that the polyhouse system consuming relatively less water and the polyhouse had higher concentration of water vapour near the inner surface of the polyhouse while dry microclimate observed near the ground during day time (Sachin and Joshi, 2021). The polyhouse had lesser average temperature and higher relative humidity than the net houses (Khapte *et al.,* 2021).

In reviewing the opportunities for outdoor cultivation of paddy straw mushroom, it was found that the natural microclimate observed under maize intercropping system (Arunkumar, 2017) may be exploited to produce paddy straw mushroom as an intercrop in maize. Previous research in Tamil Nadu Agricultural University on outdoor paddy straw mushroom cultivation as intercrop had considered only the possibility of cultivation and did not assess the microclimate requirement for this elite mushroom as intercrop. By understanding the cardinal values of microclimate for the mushroom as intercrop, appropriate microclimate can be established through agronomic management to maximize the yield. In this context, a post graduate thesis research was undertaken at Tamil Nadu Agricultural University to determine the performance of paddy straw mushroom as intercrop under different microclimate created in irrigated maize and sole crop in polyhouse during summer and *kharif* 2022.

## MATERIALS AND METHODS

Study was conducted in both controlled and open field during summer 2022 (February to May 2022) and *kharif* 2002 (May 2022 to August 2022) at Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore. Spawn preparation was done with *Volvariella volvacea* cultures obtained from the Department of Plant Pathology, Tamil Nadu Agriculture University, Coimbatore. Paddy straw was soaked in water for 8 hours and pasteurized by steaming for one hour. A total of 160 compact sized paddy straw twist beds with 20 cm height and 40 cm diameter weighing 3 kg substrate on a dry weight basis were prepared. The paddy straw spawn bits at two per cent dry weight basis were used and coarsely ground horse gram powder was sprinkled over the spawn bits. The poly house installed at the Mushroom Unit, Dept. of Plant Pathology was used for the cultivation of straw mushrooms at controlled conditions whereas in open field, it was placed in between the row (60 x 25 cm) spacing of maize (CO 8 hybrid) crop at 45 days after sowing (Fig. 1).

There were four poly houses (3m x 2.25 m x 4 = 27sqm), each with 20 mushroom beds, for a total of 80 beds in the 27 $m^2$ polyhouse area. Similarly, four 10 sqm (4m x 2.5m) plots of maize field were intercropped with 20 mushroom beds each, for a total of 80 beds in the maize field. In polyhouse and maize field, approximately three and two beds could be accommodated per sqm area. The beds were placed by 6th April 2022 during summer crop and by 5th July 2022 during *kharif* crop. Beds placed in maize crop were kept covered with polythene sheets for the entire cropping period to maintain bed temperature and humidity. Observations such as Days For Spawn Run (DFSR), Days For Pinhead Formation (DFPF), Days For First Harvest (DFFH), Biological Efficiency (%) and Total Cropping Period (TCP) were recorded. The mushrooms were harvested between egg to maturity stage and weight was taken on a fresh weight basis. The sample of paddy straw mushroom under polyhouse and maize intercropping system are depicted in Fig. 2.

***Biological efficiency (BE)***

BE was used to assess the efficiency of substrate conversion in mushroom production and was determined as a ratio of harvested biological yield to the dry weight of the substrate. It is expressed in percentage.

$$BE = \frac{\text{Total weight (g bed}^{-1}\text{) of harvested mushrooms}}{\text{Total weight (g bed}^{-1}\text{) of substrate used}} \times 100$$

***Land equivalent ratio (LER)***

LER is the most widely used indicator in intercropping to evaluate land productivity and determine the efficacy of an intercrop.

$$LER = \frac{\text{Yield of maize in intercrop}}{\text{Yield of maize in sole crop}} + \frac{\text{Yield of mushroom in intercrop}}{\text{Yield of mushroom in sole crop}}$$

LER > 1 Yield advantage; LER < 1 Yield disadvantage; LER = 1 No yield advantage

***Crop equivalent yield (CEY)***

The yields of different intercrops are converted into equivalent yield of any one crop based on price of the produce.

CEY = Yield of maize (kg $ha^{-1}$) + (Yield of intercropped mushroom x mushroom price per kg/maize price per kg)

Since the paddy straw mushroom is of elite grade, highly nutritious and tasteful, the straw mushroom is being sold @ Rs. 300/- per kg, where the Oyster and button mushrooms are being sold @ Rs. 150/- per kg. In view of preparation of beds and saleability, a farmer can maintain maximum of 10 cents for the intercropping of mushroom (*i.e*., 800 bed) in a hectare of farm.

## RESULTS AND DISCUSSION

***Growth and yield parameters***

Microclimate variables observed under maize + mushroom intercropping system and polyhouse sole mushroom are presented in Table 1. The growth and yield parameters of mushroom during summer and *kharif* 2022 are detailed in Table 2. During sum-

**Table 1:** Microclimate prevailed during the growth phases of paddy straw mushroom

| Days for growth phases | | Temp. °C 07:22 | Temp. °C 14:22 | RH (%) 07:22 | RH (%) 14:22 | Rainfall mm | Irrigation mm |
|---|---|---|---|---|---|---|---|
| **Summer - Maize intercrop** | | | | | | | |
| DFSR | 10 | 26.3 | 32.1 | 89.2 | 62.6 | 9.7 | 100.0 |
| DFPF | 12 | 26.4 | 33.2 | 90.1 | 58.0 | 0.5 | 0.0 |
| DFFH | 14 | 25.9 | 32.7 | 90.0 | 65.9 | 30.0 | 0.0 |
| TC | 24 | 26.9 | 33.0 | 89.9 | 60.9 | 41.2 | 150.0 |
| **Summer - Polyhouse** | | | | | | | |
| DFSR | 8 | 29.5 | 36.8 | 95.1 | 80.3 | | |
| DFPF | 10 | 28.1 | 37.3 | 94.5 | 78.5 | | |
| DFFH | 11 | 29.0 | 38.7 | 95.0 | 78.0 | | |
| TC | 20 | 29.4 | 37.6 | 95.2 | 79.4 | | |
| **Kharif - Maize intercrop** | | | | | | | |
| DFSR | 9 | 24.6 | 26.2 | 83.3 | 67.4 | 30.5 | 50.0 |
| DFPF | 11 | 25.3 | 26.4 | 83.0 | 66.3 | 7.0 | 0.0 |
| DFFH | 13 | 25.8 | 27.9 | 83.5 | 64.8 | 4.0 | 50.0 |
| TC | 23 | 24.8 | 26.9 | 85.4 | 66.3 | 73.5 | 150.0 |
| **Kharif - Polyhouse** | | | | | | | |
| DFSR | 8 | 27.0 | 30.5 | 89.9 | 78.9 | | |
| DFPF | 9 | 26.4 | 30.8 | 96.0 | 80.0 | | |
| DFFH | 11 | 27.9 | 31.1 | 87.5 | 76.5 | | |
| TC | 19 | 27.5 | 31.3 | 91.0 | 78.3 | | |

**Fig. 1:** Paddy straw mushroom beds under polyhouse and maize field

mer 2022, the microclimate variable such as morning and afternoon temperature, morning and afternoon relative humidity ranged from 24 to 29 °C, 27 to 35 °C, 81 to 96 per cent and 50 to 86 per cent, respectively under the mushroom intercropping situation, whereas they were 28 to 31°C, 32 to 40 °C, 93 to 99 per cent and 70 to 89 per cent, respectively in poly house. During *kharif* 2022, the morning and afternoon temperature, morning and evening relative humidity ranged from 23 to 26 °C, 25 to 39 °C, 70 to 98 per cent and 53 to 76 per cent, respectively under the mushroom intercropping situation, whereas they were 26 to 29 °C, 29 to 33 °C, 80 to 98 per cent and 66 to 88 per cent, respectively in poly house.

In both summer and *kharif* 2022, the days taken for spawn running and pinhead formation was lesser under polyhouse compared to maize intercropped mushrooms. During summer 2022, the polyhouse had 1.9 days earlier for spawn running, 2.3 days earlier for pinhead formation, 2.3 days earlier for first harvest and 4.7 days earlier for the entire mushroom cropping period than maize intercropped mushroom. Similarly, during *kharif* 2022, the polyhouse had 1.7 days earlier for spawn running, 1.8 days earlier for pinhead formation, 2.2 days earlier for first harvest and total 3.8 days earlier than maize intercropped mushroom. This may be due to optimal temperature and relative humidity prevailed in polyhouse, when

**Table 2:** Growth and yield parameters of mushroom under different microclimate

| Cropping system | DFSR (Days) | DFPF (Days) | DFFH (Days) | TCP (Days) | BE (%) |
|---|---|---|---|---|---|
| ***Summer* 2022** | | | | | |
| Polyhouse | 8.2 | 9.5 | 11.3 | 19.7 | 20.1 |
| Maize | 10.1 | 11.8 | 13.6 | 24.4 | 15.6 |
| t-value | 3.04* | 3.09* | 2.73* | 4.33** | 3.88* |
| p-value | 0.028 | 0.027 | 0.034 | 0.0075 | 0.011 |
| ***Kharif* 2022** | | | | | |
| Polyhouse | 7.5 | 8.9 | 10.6 | 19.3 | 22.7 |
| Maize | 9.2 | 10.7 | 12.8 | 23.1 | 17.0 |
| t-value | 2.59* | 2.59* | 2.65* | 5.26** | 4.44** |
| p-value | 0.048 | 0.048 | 0.038 | 0.0062 | 0.0044 |

** 1%,* 5%

**Table 3:** Land equivalent ratio (LER) and crop equivalent yield (CEY) of maize intercropped with paddy straw mushroom

| Crop | Maize yield kg ha$^{-1}$ | Mushroom yield kg ha$^{-1}$ (0.10 acre or 0.04 ha) | LER | CEY* kgha$^{-1}$ |
|---|---|---|---|---|
| **Summer 2022** | | | | |
| Polyhouse Sole crop | 4510 | 723 (1200 beds) | | |
| Maize Intercrop | 4972 | 374 (800 beds) | 1.62 | 10582 |
| ***Kharif* 2022** | | | | |
| Sole crop | 5267 | 817 (1200 beds) | | |
| Intercrop | 6160 | 408 (800 beds) | 1.67 | 12280 |

* price of Maize grain – Rs. 20/kg and paddy straw mushroom - Rs. 300/kg

**Fig. 2:** Fruiting of paddy straw mushroom in poly house and maize intercrop

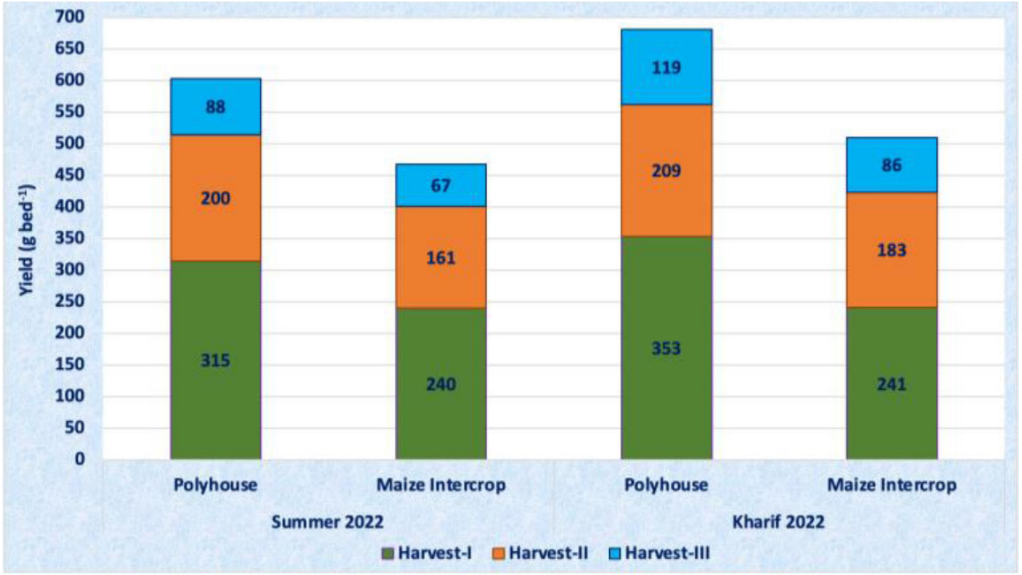


**Fig. 2:** Fruiting of paddy straw mushroom in poly house and maize intercrop

compared to maize field. The outcome was consistent with Ahlawat and Arora's (2016) conclusion that fruitification was better at temperature of 30 °C, 80 per cent relative humidity, fluorescent light and occasional fresh air.

In polyhouse, there was less difference between the minimum and maximum values, which promotes uniform spawn runs and speeds the growth phases, especially the pinhead formation phase. Contrarily, the greater variability in maize fields brought by diurnal impacts restricted spawn running uniformity and retarded the growth phases. These impacts were clearly reflected in yield parameters, where the polyhouse gave 28.8 and 33.5 per cent higher fruiting body yield than intercropped mushroom, respectively for summer and *kharif* 2022. The BE observed in this study (15 to 22) was similar to the results of Thiribhuvanamala *et al*., (2021). Between summer and *kharif*, the growth phases were little earlier with higher yield in *kharif*, which proved that the microclimate prevailed during *kharif* 2022 was more ideal than the summer 2022.

Paddy straw mushrooms were harvested in three cycles, with the first harvest accounting for half of the overall production in both the polyhouse and the maize intercrop, then decreased during 2nd and 3rd harvest (Fig. 3). The per bed mushroom yield was 28 and 33 per cent higher in polyhouse than the maize intercrop during Summer and *kharif*, respectively. It's interesting to note that the paddy straw mushroom yield was evenly distributed over the three harvests in the polyhouse during the summer, while it was evenly distributed in the maize intercrop during the *kharif*.

***Economic viability***

The results on land equivalent ratio (LER) and crop equivalent yield (CEY) of maize + mushroom intercropping is detailed in Table 3. Despite having a lower straw mushroom yield than a polyhouse, maize intercropped mushrooms offered the chance to grow paddy straw mushrooms, a high-value intercrop. The findings implied that, compared to sole maize, a one ha maize field with 10 cents of mushroom intercropping had LER of higher than 1.6.

Under the maize + mushroom intercropping system, the CEY was 10582 and 12282 kg $ha^{-1}$, compared to 4517 and 5267 kg $ha^{-1}$ during the summer and *kharif*, respectively. Similar results were obtained by Nagarajan and Anbumani (2017) that intercropping maize + mushrooms was more productive compared to sole cropping of maize and mushroom (polyhouse) and inferred that the straw mushroom beds between maize crop rows acted as mulching material and thus suppress weed growth.

Recent research on intercropping systems of maize and mushrooms showed an increase in maize yield and land equivalent ratio (Wang 2009 and Yang *et al*., 2020). According to Jayakumar and Manoharan (2015), paddy straw mushrooms can be successfully produced as an intercrop in maize crops after 45–50 DAS due to the favourable microclimate created under maize canopy. The results from this study also proved that the microclimate prevailed in maize field from tasseling to milking stage (40 DAS to 75 DAS) were ideal to produce economically viable paddy straw mushroom during both summer and *kharif*.

## CONCLUSIONS

Study on the microclimate of maize canopy for growing paddy straw mushroom as intercrop concluded that the *kharif* season was more favourable for producing higher straw mushroom yield. The polyhouse resulted with higher mushroom yield through controlled microclimate however the higher infrastructural investment is not affordable for the small and marginal farmers. The most ideal limits of microclimate variables identified for paddy straw mushroom cultivation as maize intercrop are 26 to 29 °C, 29 to 33 °C, 80 to 98 per cent and 66 to 88 per cent, respectively for morning and afternoon temperature, morning and afternoon RH.

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