Original Research Article

EFFECT OF MICROCLIMATE MODULATION ON THE GROWTH AND YIELD OF STRAW MUSHROOM AS A INTERCROP IN MAIZE FIELD DURING SUMMER

Abstract

A field experiment was carried out during the summer season to study the effect of microclimate modification on growth and yield of paddy straw mushroom under outdoor cultivation as maize intercrop. A Randomised Complete Block Design (RCBD) with eight treatments comprising the combination of spacing (60 x 25 cm, 45 x 25 cm, paired row 45/75 x 25 cm, and paired row 30/60 x 25 cm) and mulching (with or without application), in three replications was used for this study. The study concluded that maximum average yield was obtained in normal spacing 45x25 cm coupled with mulching (578 g bed^{-1}) with high biological efficiency of 19.3 per cent. The results inferred that both the afternoon (14.22 hours) microclimate variables *viz.*, temperature (low) and relative humidity (high) had played major role for higher yield and Biological Efficiency (BE) of paddy straw mushroom as maize intercrop. Normal row spacing (45 x 25cm) with or without mulch and paired row spacing (30/60 x 25 cm) with mulch provided favourable microclimate during summer for faster growth, higher yield and biological efficiency for paddy straw mushroom intercropped maize which in turn might be adopted by the farmers for the outdoor cultivation of paddy straw mushroom.

Keywords: *Volvariella volvacea*, maize intercropping, microclimate, spacing, mulch.

1. INTRODUCTION

Agriculture is still the prime sector of the Indian economy and shares in Gross Domestic Product (GDP) again reached the 20 per cent mark by 2020-21 after 17 years, previously by 2003-04. Intergovernmental Panel on Climate Change stated that the increased climate change stress would hurt food security and nutrition, especially in developing countries by increasing the frequency, intensity and severity of heat waves, floods and droughts on food availability and production. According to *IPCC AR6*, the negative impact of anthropogenic warming trends from 1961 to 2017 was projected by one worldwide research using an empirical model to be, on average, 5.3 per cent for three basic crops (5.9% for maize, 4.9% for wheat and 4.2% for rice) [1].

Intercropping is a low-input smallholder system adaptation technique that can boost output in the face of both temporal and spatial climate change.In cereal based intercropping, maize has been recognized as a key crop and is regarded as the base crop in the additive series. A land equivalent ratio greater than one was found in all of the intercropping systems studied using maize as the base crop, proving that intercropping was preferable to mono-cropping [2]. Wide row spacing is commonly used in maize cultivation, and inter row space can be effectively used to generate additional profits [3].

The geographic arrangement of component crops influences intercropping production. Planting geometry has a major influence on canopy structure and light absorption, both of which have a large impact on crop yield. Planting in paired rows, on the other hand, enables the inclusion of a complementary crop to increase overall yield without diminishing the number of maize plants.Advantage of intercropping over monocropping is that it enhances production by improving resource collection and use efficiency in areas like light, water, temperature, and humidity. Anthony and Rene showed that intercropping lower canopy temperature because of the advantages of having two crops, including enhanced land cover, higher soil moisture retention, reduced soil surface evaporation, and increased relative canopy moisture during 2008 [4]. He and his co-workers stated that intercropping alter the microclimate, especially in terms of temperature, RH, and light intensity [5]. According to findings of Dahmardeh, intercropping systems increased soil moisture, temperature, soil N, and yield when compared to cultivation of solo crops [6]. The intercropping system's modulated microclimate that has created an environment that is more conducive to growth and high output than solo crops.

Paddy straw mushroom is also referred to as “warm mushroom” as it grows at a relatively high temperature. The third-largest cultivated fungus in the world, paddy straw mushrooms (*Volvariella volvacea*), are prized for their delectable flavour and can be used as a table dish from 10 days of their seeding[7, 8]. The ideal temperature and relative humidity for straw mushroom growth are 30-35°C and 80-90 %, respectively [9, 10]. The species grows in tropical weather at around 30-35°C for the mycelia development stage, and at around 28-30°C for the fruiting body production stage [11].

Biological efficiency of this mushroom variably depends on the orientation of beds, compactness, shape and number of beds. Garcha and his co-workers reported a significant increase in the production of fruiting bodies on the helix and tyre type beds [12]. Beds are covered with polythene sheets, which might promote mycelial ramification by maintaining a constant temperatureand showing higher yield [13, 14]. The fruit body yield of *V. volvacea* is significantly influenced by the Volvariella strain's yielding potential, the cultivation methods employed, and the climate conditions maintained throughout the entire cropping cycle [15].

Mulching modulates the soil temperature and moisture regime by altering surface evaporation in addition mulches improve soil structure and moisture retention while inhibiting weed growth [16, 17, 18, 19].In a natural microclimate under maize, outdoor paddy straw mushroom growth produces high returns with little modifications[8].

Outdoor paddy straw mushroom cultivation may be successful by utilising the favourable microclimate offered by the rows of crops in order to generate large yields with little expenditure. The management strategies for intercropping the paddy straw mushroom are believed to work best with the microclimate that predominates in maize crop's wider row spacing. Despite the fact that there has been little research on intercropping paddy straw mushrooms and these studies had only been conducted in specific microclimates.

In this context, the postgraduate thesis study entitled "Optimizing weather requirements to maximize yield potential of maize intercropped paddy straw mushroom *(Volvariella volvacea)*" was undertaken at Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore to fill the research gap related to the microclimate and its modifications for intercropping paddy straw mushroom in maize.

2. MATERIALS AND METHODS

A field experiment was conducted at the Eastern Block Farm, Tamil Nadu Agricultural University, Coimbatore, during summer 2022 to assess the various agronomic management options to create suitable microclimate for paddy straw mushrooms (*Volvariella volvacea*) intercropped in maize.

During the summer season (February to May 2022), the total quantity of rainfall received during the maize growing period was 59 mm in 5 rainy days, compared to 41 mm in 3 wet days during mushroom cultivation with weather data obtained from class A observatory of Agro Climate Research Centre. Summer 2022 average Tmax and Tmin were 33.9°C and 22.8°C, respectively, for maize and 34.6°C and 24.6°C, respectively, for mushroom cultivation season. The mean Relative Humidity (RH) of summer 2022 at 0722 hours and 1422 hrs was 83 and 44 %, respectively, for maize and 84 and 50 %, respectively for mushroom growing period. Bright Sunshine hours was 7.1 hours day^{-1} with the mean solar radiation of 348 Cal cm^{-2} day^{-1} for maize and 7.1 hours day^{-1} and 321 Cal cm^{-2} day^{-1} for mushroom growing period, respectively. The mean wind speed and evaporation during the entire maize cropping period were 5.6 kilometer per hour (km/hr) and 6.1 mm day^{-1}, respectively. The mean wind speed and evaporation during the mushroom cropping period was 4.6 km/hr and 5.7 mm day^{-1}, respectively.

Field experiment having eight treatments was conducted in Randomized Complete Block Design (RCBD) with three replication. Main crop is TNAU (Tamil Nadu Agricultural University) maize hybrid CO 8 under irrigated conditions. The micro climate modification was managed by maize row spacing; planting method and mulching as per the treatment schedule (Table 1). Other cultivation operations of maize were done in accordance with the recommendations of the Crop Production Guide (CPG, 2020). Paddy straw was used as mulch. The statistical analysis of data was done using ANOVA technique for Random Complete Block Design at 0.05 probability level utilising the AGRES software.

Table 1 Treatment details

Treatment Number	Particulars
T_1	60 cm × 25 cm spacing
T_2	45 cm × 25 cm spacing
T_3	45/75 × 25 cm paired row spacing
T_4	30/60 × 25 cm paired row spacing
T_5	T_1 + Mulching
T_6	T_2 + Mulching
T_7	T_3 + Mulching
T_8	T_4 + Mulching

2.1. Mushroom intercropping in Maize

Totally 192 compact beds (8 beds × 8 treatments x 3 replications) measuring 20 cm in height and circumference of 30 cm in diameter were prepared using 3 kg (dry weight) pasteurized paddy straw twists as substrate for each bed. Roughly powdered Horse gram powder (2% of the substrate) was mixed with paddy straw mushroom spawn pieces (2% of the substrate) and sprinkled on top of the bed, which was approximately amounting 2 per cent of the beds dry weight. This mushroom cropping periods was concurrent with the intercropped maize period of 55 to 85 days after sowing of maize and the layout of intercropping was depicted in Figure 1. In order to keep out extraneous objects, to keep moisture and heat in, these beds were covered with semi-transparent blue polythene covering throughout the mushroom cropping cycle.

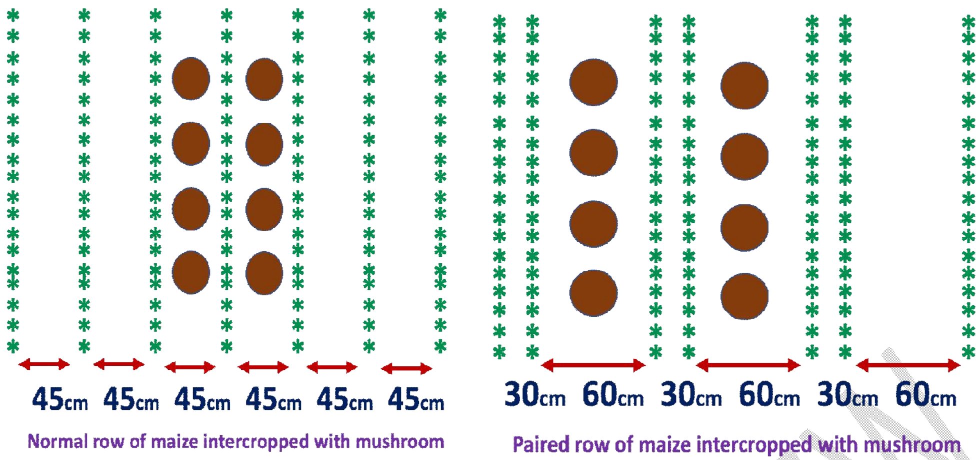


Figure 1 Layout of maize intercropped in maize

2.2. Microclimate observations

Air temperature and relative humidity inside the maize canopy was observed at 07.22 and 14.22 IST (Indian Standard Time).

2.3. Growth and yield of paddy straw mushroom

Number of days to complete the important growth stages such as Number of Days for Spawn Running (DFSR), Days for Pin Head (DFPH), Days to First Harvest (DFFH) and total duration to complete the life cycle were observed in every plot. Totally three harvests had done and weighed using weighing balance plot wise for each harvest. The mushroom yield was expressed in gram per bed (g bed^{-1})

2.4. Biological efficiency (BE)

BE had 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.

$$\text{BE (\%)} = \frac{\text{Total weight (kg) of harvested fresh mushrooms}}{\text{Total dry weight (kg) of substrate used}} \times 100$$

3. RESULTS AND DISCUSSION

3.1. Agronomic management on the microclimate

Mean microclimate variable such as air temperature and relative humidity observed during the cropping period was detailed in Table 2. Mean temperature under in different treatments ranged from 26.6°C to 27.9°C during 0722 hours and 30.5°C to 33.4°C during 1422 hours. Between the treatments, the variation in temperature within the plant canopy was higher during the afternoon than morning hours.

Table 2 Influence of Row spacing and mulching on the microclimate of maize crop

Treatment		Temperature (°C)		Relative Humidity (%)	
		Field 07:22	**Field 14:22**	**Field 07:22**	**Field 14:22**
T1	Normal 60x25cm	26.6	33.0	89.5	61.0
T2	Normal 45x25cm	26.9	32.8	90.4	63.9
T3	Paired row 45/75x25cm	26.4	33.4	88.9	58.3
T4	Paired row 30/60x25cm	26.7	32.5	89.9	62.3
T5	T1 + Mulching	27.2	31.8	90.1	61.6
T6	T2 + Mulching	27.9	30.5	91.9	65.0
T7	T3 + Mulching	27.0	31.8	89.8	59.2
T8	T4 + Mulching	27.5	30.8	91.6	63.2
	Mean	**27.0**	**32.1**	**90.3**	**61.8**
	SEd	**0.34**	**0.27**	**0.63**	**0.46**
	CD (0.05)	**0.73**	**0.58**	**1.35**	**0.99**

Lowest temperature during 07.22 hours was observed in 45/75 x 25 cm spacing without mulching, whereas the same spacing with mulching registered lowest temperature during 14.22 hours. The wider spacing paired row planting 45/75 x 25 cm recorded highest temperature (33.4℃) within the plant canopy during 14:22 hours, followed by 60 x 25 cm normal planting. This might be due to increased interception of solar radiation inside the plant canopy under wider row spacing than the closer spacing.

Invariably the mulched plots showed lesser temperature during 14.22 than non-mulched plots. Evaporation of moisture retained by the mulches took more heat energy might be the reason for the lower temperature in mulched plot. According to Li and his co-workers mulching reduced the impact of external variables on the soil by boosting soil temperature and moderating temperature variations [17].

Mean relative humidity under maize canopy ranged from 88.9 to 91.9 % during 0722 hours while 58.3 to 65 % during 1422 hours observation. Maximum relative humidity exhibited under normal spacing 45x25 cm coupled with mulching (65.0%) and minimum in paired row spacing 45/75 x 25 cm (58.3%) during 1422 hours observation. Mulched plots can hold soil moisture which in turn increase the humidity compared to the non-mulched plots [17].

3.2. Microclimatic modification in phenophases of mushroom

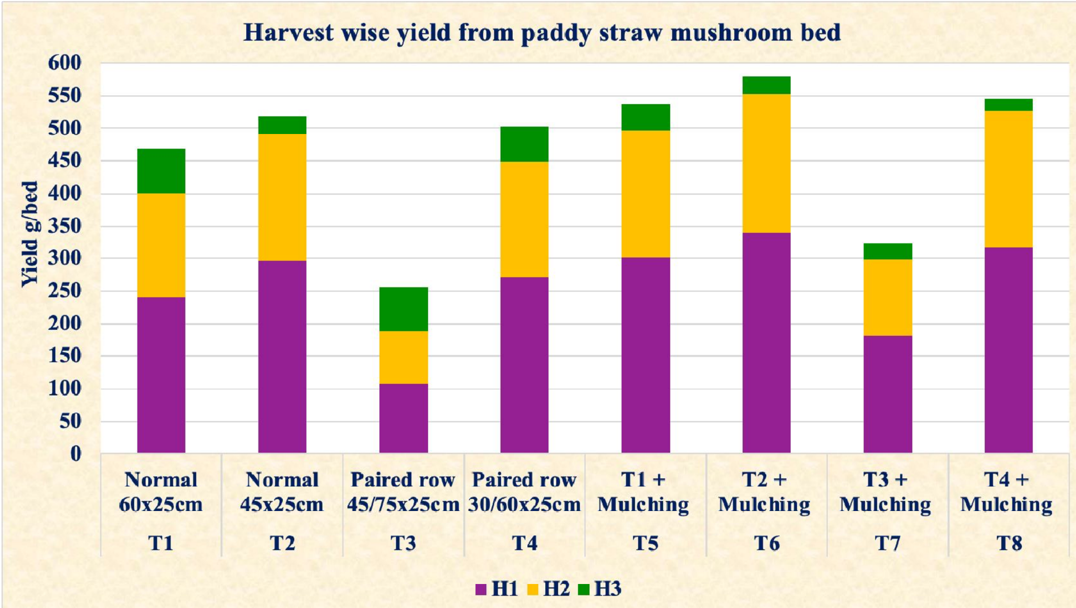
Paddy straw mushroom growth parameters observed during the field experiment are detailed in Table 3. Average days from sowing in bed observed for spawn run was ranged from 9 to 13.4 days and 10.2 to 15.3 days for pinhead formation while 11.8 to 17.2 days for first harvest. Mean total cropping period was ranged from 22.5 to 29.8 days.According to Ahlawat and his co-workers the substrate and environmental factors largely determine how long the cropping phase lasts, which usually range from 20 to 30 days [20]. Findings of Thiribhuvanamala *et al.*,inferred that the total cropping period of straw mushroom under maize canopy were less comparatively with other cropping systems [8].

Table 3 Influence of microclimate modification on the important phenophases of mushroom under maize inter-crop

	Treatments	DFSR	DFPF	DFFH	TCP
T1	Normal 60x25cm	10.1	11.3	13.6	24.4
T2	Normal 45x25cm	9.4	10.8	12.5	23.7
T3	Paired row 45/75x25cm	13.4	15.3	17.2	29.8
T4	Paired row 30/60x25cm	9.9	11.3	13.2	24.4
T5	T1 + Mulching	9.5	10.7	12.4	23.5
T6	T2 + Mulching	9.0	10.2	11.8	22.5
T7	T3 + Mulching	12.1	13.9	15.8	27.2
T8	T4 + Mulching	9.6	11.0	12.7	23.0
	Mean	**10.4**	**11.9**	**13.6**	**24.8**
	SEd	**0.5**	**0.6**	**0.7**	**1.3**
	CD (0.05)	**1.2**	**1.3**	**1.5**	**2.8**

Days for Spawn Running (DFSR) in days, Days for Pin Head (DFPH) in days, Days to First Harvest (DFFH) in days and Total Cropping Period (TCP) in days.

During this study, maximum cropping period had observed under paired row with spacing 45/75x25 cm while minimum in normal spacing 45x25 cm coupled with mulching.The higher temperature and lower relative humidity under the wider paired row spacing (45/75x25 cm) without mulching become unfavourable for the paddy straw mushroom growth, whereas the lower temperature and higher humidity under closer row spacing with mulch fasten the spawn running and pinhead formation. The above impact was clearly observed in the harvest wise yield that exhibited in Figure 2.



H1- First harvest, H2-Second harvest, H3-Third harvest

Figure 2 Influence of microclimate modifications on the harvest wise mushroom yield

Highest yield in first harvest was recorded in mulched plots with closer spacing (45x25cm) followed by the wider spacing (60x25cm) with mulch. Similar trend was observed in other mulched plots. Application of mulch had lowered the temperature and elevated the relative humidity during summer, which creates favourable environment for the paddy straw mushroom that resulted infaster harvest. The wider spacing paired row (45/75x25 cm) with and without mulch recorded lowest harvest in all three harvests.

3.3. Effect of microclimatic modification on yield and biological efficiency of mushroom

Effect of microclimatic modification on the yield of mushroom and its biological efficiency was given in Table 4. Average yield of mushroom ranged from 238 to 626 g bed^{-1}. Maximum average yield obtained in normal spacing 45x25 cm coupled with mulching (578 g bed^{-1}) while minimum in paired row 45/75x25 cm (256 g bed^{-1}).

Mean biological efficiency of mushroom ranged from 7.9 to 20.9 %. Maximum mean biological efficiency was obtained in normal spacing 45x25 cm coupled with mulching (19.3%) while minimum in paired row 45/75x 25 cm (8.5%). According to Thiribhuvanamala and her co-workers, *Volvariella volvacea* can be cultivated successfully from March to September with 18-20 per cent biological efficiency and outdoor cultivation of paddy straw mushroom yields good returns with low investment under maize cropping system with natural microclimate [7, 8].

Table 4 Effect of microclimate modification on the mushroom yield and biological efficiency

	Treatment	Yield g/bed				Biological efficiency (%)			
		R1	R2	R3	Mean	R1	R2	R3	Mean
T1	Normal 60x25cm	477	491	435	**468**	15.9	16.4	14.5	**15.6**
T2	Normal 45x25cm	493	555	508	**519**	16.4	18.5	17.0	**17.3**
T3	Paired row 45/75x25cm	267	238	264	**256**	8.9	7.9	8.8	**8.5**
T4	Paired row 30/60x25cm	533	473	523	**510**	17.8	15.8	17.4	**17.0**
T5	T1 + Mulching	516	526	569	**537**	17.2	17.5	19.0	**17.9**
T6	T2 + Mulching	551	626	556	**578**	18.4	20.9	18.6	**19.3**
T7	T3 + Mulching	317	333	320	**323**	10.5	11.0	10.6	**10.7**
T8	T4 + Mulching	524	519	595	**546**	17.5	17.3	19.8	**18.2**
	Mean	**460**	**470**	**471**	**467**	**15.3**	**15.7**	**15.7**	**15.6**
	SEd				**26**				**0.9**
	CD (0.05)				**57**				**1.9**

R1, R2, R3 - Replications

According to Ahlawat and Tewari optimum temperature and relative humidity for the growth of straw mushrooms are, respectively, 30-35°C and 80-90% [21].Results from this microclimate modification clearly inferred that the normal planting had reduced the interception of solar radiation and promoted the favourable microclimate for the paddy straw mushroom, whereas the application of mulches added value to it by reducing the temperature and increasing the relative humidity under irrigated maize canopy.Importantly, both the afternoon (14.22 hours) microclimate variables *viz.*, temperature (low) and relative humidity (high) had played a major role in higher yield and BE of paddy straw mushroom as maize intercrop.

4.CONCLUSION

Study on the microclimate modification to improve the growth and yield of paddy straw mushroom under outdoor cultivation as maize intercrop indicated that maximum average yield was obtained in normal spacing 45x25 cm coupled with mulching (578 g bed^{-1}) with high biological efficiency of 19.3 per cent. It also concluded that the closer normal row spacing (45 x 25cm) with or without mulch and closer paired row spacing (30/60 x 25 cm) with mulch during summer provided favourable microclimate for faster growth, higher yield and biological efficiency. Cultivation of paddy straw mushroom in the outdoor conditions especially under maize might fetch additional income for the farmers.

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