Mushroom Biology and Mushroom Products, Royse (ed.) © 1996 Penn State Univ. ISBN 1-883956-01-3

Air Flow Effects on Mushroom Production

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ABSTRACT: Air-flow observations in mushroom houses using lightweight indicators (flags) showed that where there was a linear flow pattern along the long axis of the growing surface, there were problems with crop production. A series of experimental crops at the Mushroom Test Demonstration Facility were placed in controlled air flow situations to measure the effect of air flow on production after pin set. The air flow was constrained to travel along 3 meters of growing surface, so that air temperature, moisture content, and gaseous components of the air could change without the effect of dilution by room air. The timing of the peak harvest day was the most noticeable result of these experiments. Temperature, moisture, and CO_2 changes and yield data are reported. For example, the largest change in CO_2 concentration was 16 ppm for the 3 meter distance, which would indicate a CO_2 production rate of about 1 g CO_2 per sq m per hr. This rate occurred just before a day's harvest of 6.5 kg of mushrooms per sq m of growing surface (1.33 lbs/sq ft).

1 INTRODUCTION

The importance of air quality and movement for growing mushrooms has been known for many years (Styer 1933). As more sophisticated controls for temperature and air properties have become available, and as higher production per unit area has been realized, there is need for better understanding of the influence that air has on the growing mushrooms. Flegg (1974) reported measurements of air velocity and humidity relative to evaporation, and others have referenced that information (Edwards 1978), but there has been limited experimental effort until recently. Loeffen (1995) reported on carbon dioxide production in terms of temperature and he noted other studies on CO_2 change as related to variation in yield.

This report is based on two experimental crops grown at Penn State University's Mushroom Test Demonstration Facility (MTDF) in January and June, 1995. This mini-farm uses small trays, 1.4 by 1.4 meters to demonstrate commercial practices on a research scale. The building and typical production practices were described by Schroeder *et. al.* (1981) after ten years of operation. The room climate control system uses a micro-computer based system (Automated Environments, Inc.) for temperature, humidity, and carbon dioxide control as well as for documentation of those properties.

2 MATERIALS AND METHODS

2.1 *Room plan*

The production room (after pin set) at the MTDF contained two rows of four stacks of trays (Fig. 1). Each stack was six trays high with an empty tray on top. Polyethylene curtains were rolled down along each side of the two rows to constrain air flow from one end to the other on each level. The curtains were rolled up for watering and harvesting.

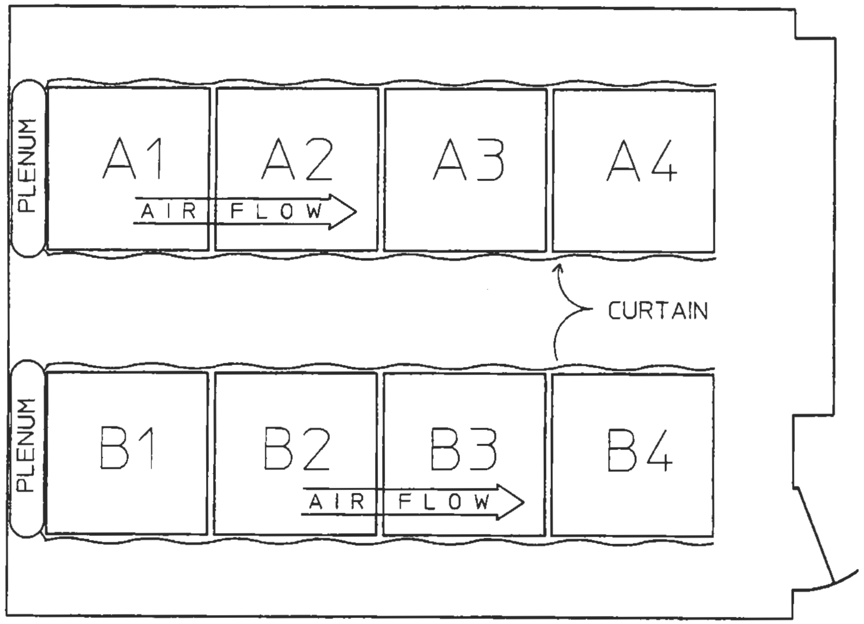

Figure 1. Plan view of production room showing eight stacks of trays.

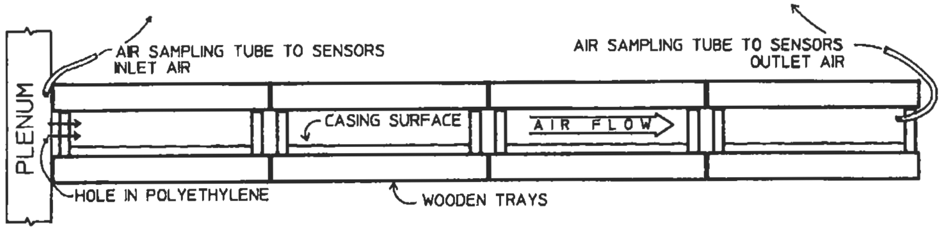

Figure 2. Side view of four stacks showing air flow from left to right.

Air was supplied to the end of each stack from a plenum, a polyethylene bag 1.33 m wide, 3 m high, and .20 m thick, with 2 cm holes at each level above the casing surface. Each plenum was filled by a centrifugal blower moving mixed room air. The regular air circulation system for the room remained as usual with a central duct along the ceiling and nozzles aimed at the wall (Schroeder *et. al.* 1976). The system of added blowers provided mixed room air and not the cold, dry air from the duct system. The number of 2 cm holes for each level was experimentally determined by measuring the velocity of the air using air flow indicators (Lomax *et al.* 1995) at the most distant tray away from the air supply. The target air flow for the January, 1995, crop was 30 cm/sec. For the June, 1995 crop, air flow was set slower within the range 15-25 cm/s. Fig. 2 shows a typical level with the points of measurement in air and substrate to compare the inlet and outlet air properties.

2.2 *Production practices*

Standard substrate preparation (Phase I and Phase II), spawning, casing and other growing procedures of the Mushroom Test Demonstration Facility were followed (Beyer and Beelman 1995). The January crop was spawned with Lambert 900, hybrid off-white strain, and the June crop was spawned with N. American 670, hybrid off-white strain. The spawn grew for 13 days at a substrate temperature of 25 °C ± 0.5 °C. At casing time, ground soybeans, at a rate of 0.08 kg per kg of dry substrate, were added to the fully grown spawned substrate. Casing consisted of peat moss mixed with agricultural, ground limestone at 18 kg per bale (40 kg) of peat (one-half bag of limestone per bale of peat moss). Peat moss was moistened to near capacity after limestone was mixed with it. CAC (compost added at casing) was mixed just prior to applying the casing to the substrate. Fully grown spawned substrate (CAC) was broken up and added at a rate of 0.73 kg per m^2. Casing was applied in a 4.0 cm layer. Standard watering procedure was used to quickly raise the casing moisture level to saturation.

2.3 *Instrumentation and measurements*

Humidity of the air was measured with a chilled-mirror type dew point temperature meter (Omega Model RHB-1). All temperatures, both dry bulb air temperature and substrate temperature, were measured with themocouples. Carbon dioxide concentration was measured with a Horiba Model APBA-210, calibrated to ambient air. Air from two inlet points and two outlet points was drawn through a stream-selector sampler unit containing sensors to measure the change in moisture and carbon dioxide. This sampler unit was controlled by the data recorder so that each sample tube was connected for two minutes on a continually cycling sequence. The data recorder was a Campbell Scientific CR10 connected to a data storage unit. The data was down-loaded to a personal computer and imported into Lotus 123 for analysis.

Yield of mushrooms was determined each day of harvest by hand picking and cutting off the stems for fresh market. Harvest from each stack of six trays was accumulated in a separate container (or containers) and weighed within two hours of picking. The mushrooms were not graded by size or quality but unsalable mushrooms were discarded. The two rows of trays, A and B, were replicates and the numbers designated the stacks of trays from 1 at the air inlet, to 4 at the outlet.

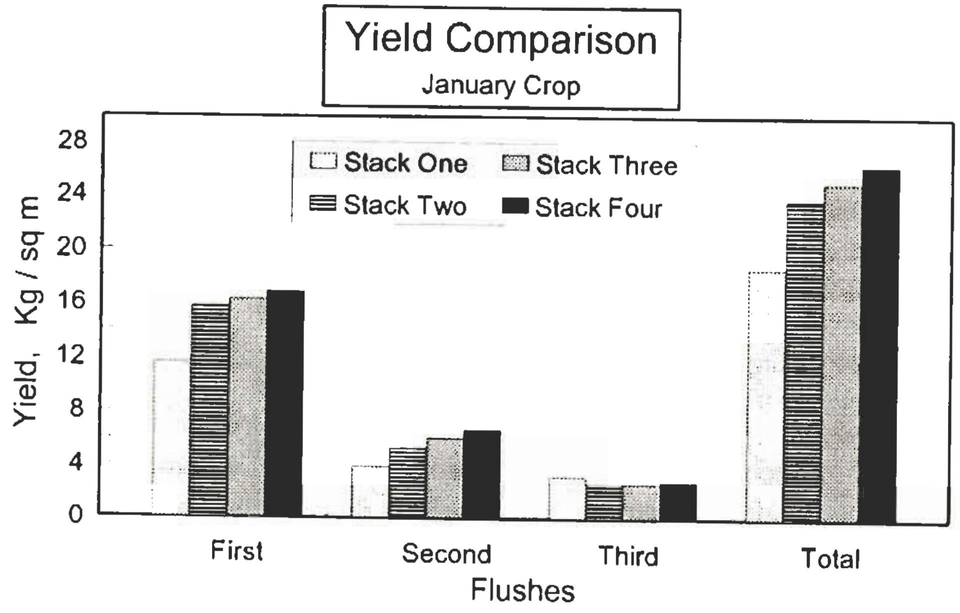

Figure 3. Mushroom harvest totals by flush averaged by four stack positions for January 1995.

3 RESULTS AND DISCUSSION

The harvest record for the January, 1995, crop is shown in Fig. 3. For this crop there was a statistically significant difference (at the .001 level) in total harvest between stack 1 and the other stacks. The air flow crossing the surface of stack 1 was cool and dry compared to the air subsequently moving across the next stacks in the sequence. For these air flow conditions, the highest yield appeared to be for the last stack.

The yield data for the crop in June, 1995 is shown in Fig. 4. There was no statistical difference in these data. The workers picking the mushrooms did not observe a noticeable variation in quality between the stacks, although there may have been a few more caps with visible blotch for Stack 4 position. For this crop where the air flow rate was slower, the last stack appeared to have slightly reduced production. A comparison of the total yield bars (Figs. 3 and 4) for the two crops shows that the different flow rates of air appeared to cause a difference as to which stack had the "best" air as indicated by the highest yield. Stack 4 had the highest in January, but Stack 2 was highest in June. The depressed yield and possible blotch problems of Stack 4 would suggest that another tray added to the end would have major problems. Where the length of flow might be longer than 3 m, as it could be on a bed, then there would be an expectation of economic loss due to such an undesirable flow pattern. Likewise, a

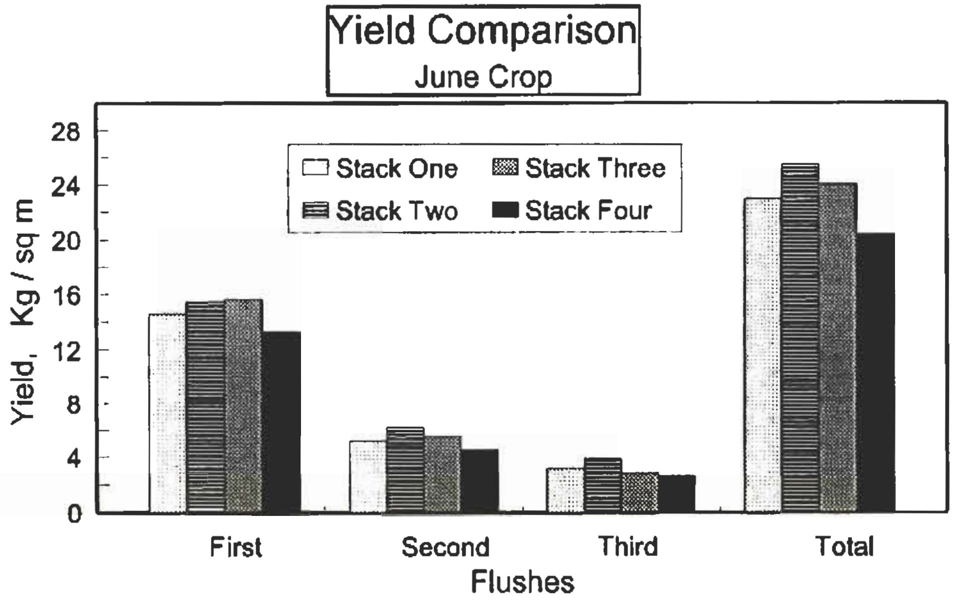

Figure 4. Mushroom harvest totals by flush averaged by four stack positions along the air flow for June, 1995.

flow pattern that provides excessive cool air would also reduce production and cause lower profits.

Figure 5 shows the average harvest by stack number per day during first flush. The peak harvest for stack 1 was one day later than for the other stacks. Stack 1 had the coolest, freshest, and driest air. Figure 6 shows the air properties for the day before first-flush harvesting began. The curtains were raised for harvesting at about 0800 hours and were open until 1300. It is interesting to note that the CO_2 production, as measured by the change in concentration, began to decrease after 0200 well before there was any worker activity in the room. The concurrent gradual increase in bed temperature might suggest that the caps of mushrooms were beginning to grow together, forming a tight canopy, and reducing the exchange of gases and heat from the casing surface. Using the highest change in carbon dioxide concentration, 16 ppm, and the area of mushrooms along the 3 m length of flow, the CO_2 production was about 1 g CO_2 per sq m of growing surface per hr. This rate occurred just before a day's harvest of 6.5 kg of mushrooms per sq m of growing surface (1.33 lbs per sq ft).

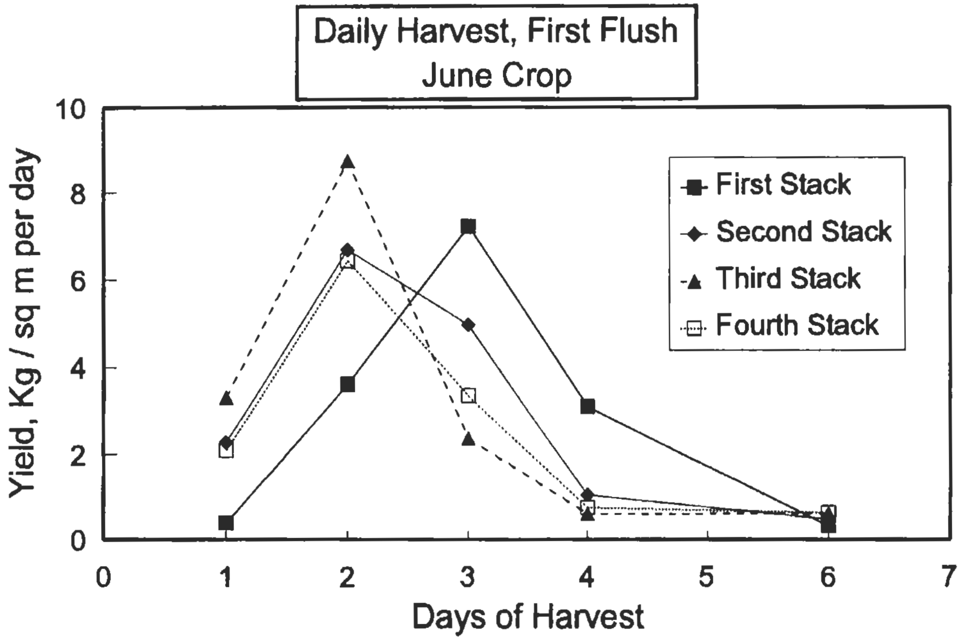

Figure 5. Harvest of mushrooms during first flush for June, 1995. Each value is the average of two stacks in the same position along the flow.

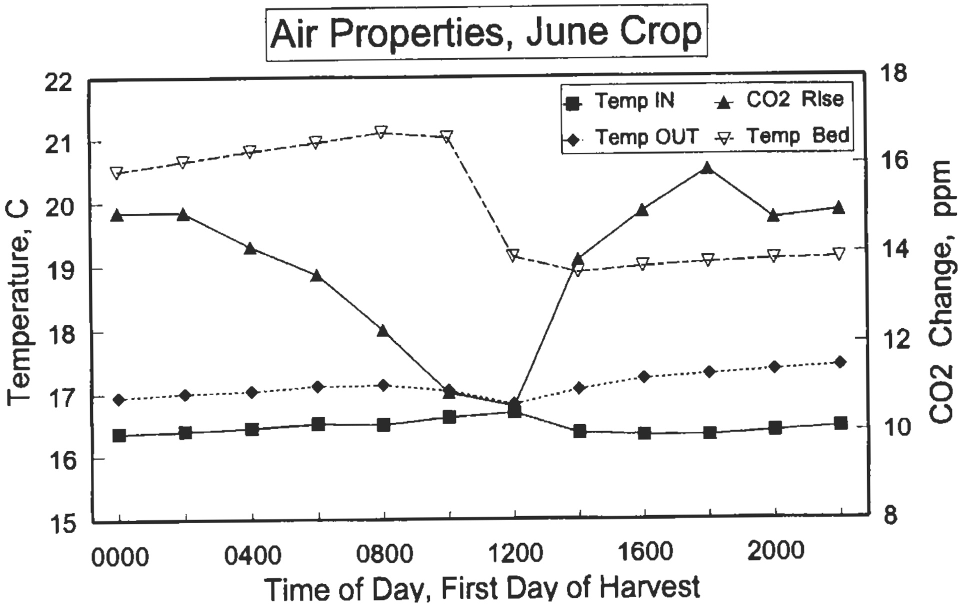

Figure 6. Air properties changed along the three meter length of the air flow.

4 CONCLUSIONS

This experiment demonstrated that a change in air properties due to mushroom growth does influence the rate of growth of the mushrooms. The value of these results for mushroom growers is to recognize that the pattern of air flow along beds (shelves) can have noticeable effect on harvest timing. For air flow rates in these tests, the air properties did not appear to cause a measurable change in quality of the mushrooms.

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