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A REVIEW OF ENVIRONMENTAL FACTORS AND MUSHROOM PRODUCTION

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CONTENTS

(a) the air temperature in the growing room should be less than 18° C

(b) the CO_2 concentration of the room air should fall below 0.15% (0.10% for certain strains)

(c) the air humidity should remain high to prevent drying out of the mycelium.

Tschierpe stated that the air temperature, humidity and CO_2 level should be varied simultaneously to cause fructification. However, a knowledge of the independent effects of these environmental factors and their interactions may enable greater control of the pinning process to be achieved.

2.1 Temperature

There is no conformity in the literature as to whether the temperature of the air, compost or casing layer should be used to control the environment during pinhead initiation. The effect of temperature during pinning, at a constant humidity and CO_2 level has been examined at the Hauser experimental station (Anon, 1984). The effect of three temperatures, 16.5, 20.0 and 23.5°C on the strains AX30, AX60 and A8.2 was determined. Lower temperatures at pinning resulted in a larger number of pinheads, and a larger number of small mushrooms. The optimum temperature at pinning depended on the strain. For the strain A8.2, which forms pinheads readily, a relatively high air temperature of 20-23.5°C was recommended, to obtain larger mushrooms. For the strain AX30, which forms pinheads less readily, an air temperature of 16.5°C at pinning was optimum, in order to obtain a sufficient number of pinheads and subsequent yield.

The rate at which the temperature is reduced also affects pinhead formation; a more rapid fall in temperature results in a greater number of pinheads (Anon, 1986). Visscher and van Geijn (1985) found that a rapid fall in temperature at pinning (compost temperature reduced from 26°C to 16-17°C in

1-2 days) resulted in a higher yield than a gradual reduction to 18-19°C in 3-4 days. The effects of equal rapid and gradual reductions in compost temperature were not studied. Ganney (1986) observed that sharp drops in temperature at airing can produce severe clumping on the first flush of hybrid strains.

2.2. CO_2 Level

The optimum level of CO_2 during pinhead formation for most hybrid stains is 0.07 to 0.09% (van Gils, 1988). A higher concentration (up to 0.14%) will result in fewer and larger mushrooms in the first flush. If the CO_2 concentration is too high, the mycelium will continue vegetative growth and subsequent yield will be reduced.

As with temperature, the rate at which CO_2 is reduced at airing also appears to influence the number of pinheads which initiate; a rapid reduction in CO_2 resulting in more initiation than a gradual reduction (Tschierpe, 1983).

With independent ventilation and cooling, it is possible to reduce the temperature and CO_2 concentration independently during pinhead initiation. This has not been studied in detail, since temperature and CO_2 level are normally reduced simultaneously when fresh air is introduced into the growing room.

The treatment of the casing can influence the CO_2 concentration close to the casing surface and therefore the amount of pinning. Extra wet casing results in fewer pinheads, due, at least partly, to more CO_2 being retained. By contrast, deep ruffling results in a greater gas exchange and more pinhead formation (Visscher, 1981).

2.3 Humidity

During pinhead initiation, it is generally recommended that the relative humidity should remain high, i.e. 87-92%

(Visscher, 1985; van Gils, 1988). During the subsequent development of the pinheads, the relative humidity should be reduced to 80-85% to enable sufficient evaporation from the beds to take place, which promotes the transfer of nutrients to the developing pinheads (Hermans, 1985; van Gils 1988). If the humidity is too high, developing pinheads, particularly of hybrid strains, will die; if it is too low, the casing will dry too quickly (Hermans, 1985). The independent effect of humidity at specific stages in pinhead initiation and development has not been studied in detail.

3. Subsequent Growth

The main objectives of environmental control following development of the pinheads is to maximize yield and quality, both at harvest and in terms of post-harvest shelf life. The effects of temperature, CO_2 level and humidity on the crop will interact, but will first be considered independently.

3.1 Temperature

The effect of air temperature on the yield and quality of different strains is well established. Work at the Hauser experimental station showed that yield of the hybrid strains AX30 and AX60 was lower at air temperatures of 20°C and 23.5°C than at an air temperature of 16.5°C. The higher air temperatures resulted in smaller numbers of large mushrooms than the lower temperature. Samp and Phelps (1986) found that the optimum temperature for U1 in terms of yield was 17.3°C. This temperature also resulted in the highest percentage of mushrooms in the 25-44 mm size range. A lower temperature (15°C) resulted in a higher proportion of small mushrooms and higher temperatures (19.5 and 22°C) resulted in higher proportions of large mushrooms, when picked on a 24 hour cycle.

Temperature also has a significant effect on quality. Okereke et al (1986) and Samp and Phelps (1986) found that mushrooms produced at cool temperatures (11-15°C) opened faster during shelf life than mushrooms grown at 17-19.5°C. However, mushrooms grown at cooler temperatures were firmer and maintained their whiteness in shelf life slightly better than mushrooms grown at high temperatures.

3.2 CO_2 Level

Early work by Tschierpe (1964) on prolific strains indicated an optimum CO_2 level of 0.06 to 0.08% for yield and quality. Slightly higher levels of 0.07 to 0.09% are now regarded as optimum for the production of hybrid strains. The CO_2 level may be increased up to 0.14% if a smaller number of heavier mushrooms are required (van Gils, 1988). If the CO_2 concentration is increased further, excessive stretching and premature opening will occur.

3.3 Humidity

The extremes in relative humidity (RH) which are likely to result in bacterial blotch or cap scaling at particular air velocities are well documented (Edwards, 1978). Within this range, the optimum level of RH for yield and quality is less well established. The high quality of mushrooms from the bag system of production has been attributed to the high air/bed ratio, and resulting low RH. In the Netherlands (Hermans, 1988) it is recommended that the RH is reduced from 90% to 80-85% once the pinheads have formed, in order to encourage evaporation from the beds, which in turn promotes the transport of nutrients to the developing pinheads. Visscher (1988) has shown that an RH of 90% has a negative effect on yield and quality compared with a lower RH.

3.4 Casing moisture

Although previous investigations have shown that higher casing moisture content results in a higher total yield and

heavier mushrooms, the effect of casing moisture content on quality is less clear. van Griensven (1985) stated that a higher dry matter content, which results from a lower casing moisture content, improves quality by producing a firmer structure of the mushroom. This has been confirmed by Beelman (1986) in mushrooms produced in trays. Post-harvest bacterial deterioration was also greater in mushrooms with a higher moisture content. Gormley (1987) however found little effect of casing moisture content in the bag system of production on mushroom whiteness and firmness.

Preliminary work at Lee Valley EHS showed that mushrooms produced in 'wet' casing (moisture content 73%) had a lower dry matter content and a higher incidence of hollow and discoloured stalks than mushrooms grown in a drier casing (moisture content 70%).

4. Synchronization of Flushing

At a standard temperature of 16-18°C, mushrooms are normally produced in flushes at intervals of about 7 days; several days are usually required to harvest all the mushrooms in each flush. Improving the synchronization of the flushing pattern of mushrooms would reduce the number of days required to pick a crop and simplify picking by reducing the number of grades of mushroom. However, the greatest benefit of more uniform stands of mushrooms would be the possibility of mechanical harvesting for fresh market.

Previous attempts to improve the synchronization of flushes of mushrooms have concentrated on the manipulation of temperature (Flegg, 1980; Love et al, 1986, 1989; Noble, 1989). Although improved synchronization of the flushing pattern of hybrid strains has been achieved by raising the temperature at defined stages in sporophore development, this has usually been at the expense of reduced yield.

As discussed in the previous sections, the CO_2 level of the air can have a great effect on the development of mushrooms. At levels above those normally found in mushroom sheds (3-4%), the stems lengthen rapidly, whereas the opening of sporophores and the development of small pinheads is suppressed. These effects would be advantageous for mechanical harvesting (Tschierpe, 1982). By artificially raising the CO_2 in the air at defined stages in sporophore development, with or without a rise in temperature, improved synchronization of growth without loss in yield could be achieved.

5. Conclusions and Areas of Further Work

1) The independent effects of temperature, CO_2 level and humidity on pinhead initiation have not been fully determined. These factors are normally changed simultaneously when fresh air is introduced into a growing room.
2) The effects of the rates of temperature and CO_2 level reductions at airing have not been fully distinguished from the effects of the size of the reductions.
3) There is no information as to whether the temperature of the air, casing or compost should be used to control the environment during initiation.
4) The effects of temperature and CO_2 level on yield and quality at harvest are well understood. The effects of environmental factors, particularly humidity and casing moisture, on the post-harvest shelf life of mushrooms have not been examined in detail.
5) The use of short durations of high, artificial levels of CO_2 to improve synchronization of flushing and to facilitate mechanical harvesting for the fresh market has not been fully investigated.

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