Crop Profile for Mushrooms in California

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General Production Information

California is second in mushroom production to Pennsylvania and produces 17% of the mushrooms grown in the United States (2).

A total of 130,200,000 lbs of mushrooms were produced on 22.78 million square feet of beds in California in 1997. The average price was $1.19/lb and the total value of the crop was $155,554,000 (2).

Production Regions

The leading mushroom production counties are Monterey, Santa Clara, San Mateo, and San Diego (4).

Cultural Practices

Mushrooms are produced in trays or fixed shelves (beds) filled with compost inside buildings called mushroom houses. Mushroom production involves several carefully controlled practices: composting, spawning, casing, pinning and harvesting. Composting, the first step in mushroom production, is the production of a nutritious substrate for mushroom growth. The major component of compost is straw to which supplements such as, urea, cottonseed meal, cottonseed hulls, alfalfa meal, cocoa hulls, sugar beet pulp, or manures are added. Gypsum is also added to improve the physical structure of the compost and to provide calcium for biological activity. Compost components are wetted, mixed, piled and allowed to compost. The piles are turned to prevent an anaerobic center. Optimum compost temperature should reach 155-170ºF. Achieving the proper composting temperatures is essential for production of a substrate semi-selective for mushroom growth. Good compost reduces the chances of fungal and bacterial problems later during mushroom growth. The compost is then loaded into trays and the trays moved inside the house. Aerated steam is piped into the room and the temperature held at 140ºF for at

least 2 hours. This pasteurizes the compost killing harmful nematodes, flies, and fungal pathogens. The temperature is then lowered slowly over several days.

When the temperature of the compost is 76-80ºF, it is inoculated with mushroom mycelium growing on millet or rye grains. Mycelium colonized grain is called spawn, inoculation is called spawning and growth of the mycelium from the grains into the compost is called spawn running. The mushroom house is maintained at 77ºF and 90% relative humidity during the spawn run.

After the mycelium has thoroughly colonized the compost a casing layer of peat moss, limestone and sugar beet lime is added to the top of the trays. The mycelium completely colonizes the casing layer in approximately three days. Then the casing is watered lightly several times to promote pinhead (mushroom primordial) formation.

Mushrooms develop from the pinheads in growth cycles or breaks. During a break many mushrooms develop more or less synchronously. The time between breaks is 7 to 10 days. Button mushrooms are picked before the stem elongates and the veil on the cap breaks open. Crimini (brown mushrooms) are also picked prior to stem elongation and breaking of the veil. Portobellos are thinned during mushroom initiation and the stems are allowed to elongate and the caps open. Trays may be picked for 2-4 breaks depending on the grower. Spent compost is steamed to kill pests and spread as organic matter in agricultural fields. There may be up to eight cycles of spawning per tray or house per year. Since there are 2-4 breaks per cycle, the number of pesticide applications per unit per year can be high. The number of pesticide applications per crop is normally few.

Some houses use bed farms, where the entire process of substrate preparation and composting takes place in the rooms. This results in a longer period of time for each crop, but only three breaks. This practice is more common in Pennsylvania than California.

General sanitation and exclusion are the best control for all insect and disease problems. The surface disinfectant calcium hypochlorite is used as a component of sanitation. In 1997, 1670 lbs calcium hypochlorite was applied to 18% of California’s mushroom acreage an average of 3 times at a median rate of 2 lbs ai/ acre.

After each crop is harvested for the last time, the spent compost is removed and new compost is brought in. Therefore, accumulation of pathogens and pesticides does not occur.

Insect Pests

Sciarid and phorid flies - *Lycoriella* spp. and *Megaselia* spp.

The major insect pests of mushroom cultivation are the sciarid (*Lycoriella* spp.) and phorid flies (*Megaselia* spp.). Both flies are attracted to fungi and decaying vegetation. They lay eggs in the compost or casing layer and the larvae may tunnel through mushrooms rendering them unmarketable. Flies may also be the primary vectors for spreading fungal, bacterial and viral diseases, mites and nematodes. The best control for flies is strict sanitation, exclusion and farm cleanliness. Mushroom houses must be airtight and all air vents must have filters. Fly populations are monitored using sticky panels near black lights. Chemical treatments are only applied when the sticky panels indicate significant fly populations in the house.

Control:

Non-chemical:
Good sanitation and filters on all air vents in the mushroom house are used to prevent flies from contaminating the trays. Beneficial nematodes applied to the casing layer have been useful in infecting fly larvae.

Chemical:
Structural or premise sprays may be used for external building surfaces, corridors, etc. Due to re-registration efforts some have been discontinued. The use of Baygon may be restricted or discontinued in coming months.

- Azadirachtin – Label has a rate of 0.02- 0.04 lb ai/acre and 4 hour REI (3). In 1997, 10 lbs azadirachtin were applied to 8% of California's mushroom acreage an average of 3 times at a median rate of 0.04 lbs/acre (1). Diazinon – Label has a rate of 2-2.5 lb ai/50 gallons of water and 24 hour REI. Diazinon is applied to mushroom house walls and floors (3). In 1997, 1980 lbs diazinon were applied to 87% of California's mushroom acreage an average of 6 times at a median rate of 22.3 lbs/acre (1).

- Diflubenzuron – Label has a rate of 0.6-1.0 lb ai/1000 ft^2 (26.1 – 43.6 lb ai/acre) of compost and 0.05 lb ai/1000 ft^2 (2.2 lb ai/acre) of casing and 12 hour REI (3). In 1997, 86 lbs diflubenzuron were applied to 15% of California's mushroom structures an average of 3 times at a median rate of 12.4 lbs/acre. An additional 617 lbs diflubenzuron were also applied to 9% of California's mushroom acreage an average of 1 time at a median rate of 4.6 lbs/acre (1).

- Methoprene – Label has a rate of 0.21 lb ai/1000 ft^2 (9.1 lb ai/acre) for compost and 0.08 lbs ai/1000ft^2 (3.5 lb ai/acre) for casing and spawn. The REI is 4 hours (3). In 1997, 111 lbs methoprene were applied to 0.2% of California's mushroom acreage an average of 1-2 times per crop.

- Permethrin – Label has a rate of 0.05 – 0.0625 lb ai/8000 ft^2 (0.27 – 0.34 lb ai/acre), 12 hour REI,

and 3 day PHI. 8000ft^2 is the size of a standard double house. Permethrin is used to fog houses for flies and must not be used once mushroom pins are present (3). In 1997, 19 lbs permethrin were applied to 62% of California's mushroom structures an average of 3 times at a median rate of 0.02 lbs ai/acre. An additional 604 lbs permethrin were also applied to 31% of California's mushroom acreage an average of 3 times at a median rate of 0.4 lbs/acre (1).

- Piperonyl butoxide and Pyrethrins – Label has a rate of 0.005-0.01 lb ai piperonyl butoxide /1000 ft^2 (0.21-0.42 lb ai/acre) and 0.004-0.008 lb ai pyrethrins/1000 ft^2 (0.17-0.34 lb ai/acre) and 12 hour REI. Piperonyl butoxide and pyrethrins are used to fog mushroom houses for flies and are not used when mushrooms are present (3). Piperonyl butoxide and pyrethrins were applied to 6% of California's mushroom acreage an average of 3 times at a median rate of 0.06 lb piperonyl butoxide and 0.01 lb pyrethrins. A total of 25 lbs piperonyl butoxide and 2 lbs pyrethrins was applied to California mushrooms in 1997 (1).

Diseases

Fungal Diseases

Dry bubble – *Verticillium fungicola*

Spores of the fungus are spread in the air, on soil, and on insects. The spores germinate and infect the mushroom mycelium. A small puffball-like mass of Verticillium spores (dry bubble) is produced instead of a mushroom. If the fungus infects during mushroom formation, it causes superficial, brown lesions on the mushroom cap or deformed stalks. Infected mushrooms are unmarketable. Isolates resistant to benomyl have been found.

Cob web – *Hypomyces* sp.

Hypomyces sp. grow over the casing layer forming a cottony mycelium. The asexual state (*Dactylium* = *Cladobotryum spp.)* forms airborne conidia that are spread by air, soil, water and insects. Hypomyces mycelium envelops the mushrooms and causes a soft. Cobweb disease is favored by high humidity and low air flow.

Green mold – *Trichoderma* spp. (*T. harzianum* is the most aggressive)

Trichoderma mycelium is white and grows rapidly over the casing layer and developing mushrooms. Masses of spores formed on the mycelium are forest green and airborne. Infection can occur at any stage of mushroom production from composting to casing. Early infections are more serious whereas later infections can be spot treated. Green mold is the most serious disease problem in mushroom cultivation. Large areas of trays may have no production. Other *Trichoderma* spp. may cause less damage to crop yield but may cause mushroom cap spotting. Strict sanitation, including disinfestation of all trays, shelving, and mushroom house structures and foot dip solutions for workers entering houses, is practiced.

Control:

Non-chemical:
Every mushroom house practices non-chemical controls. These controls include the use of high quality spawn, compost, and casing material; strict sanitation of all mushroom trays, shelves, equipment and tools, mushroom house walls and floors; and filters on all air vents.

Chemical:
The following chemical control measures are used for all three diseases.

- Benomyl – Label has a rate of 0.125 lb ai/1000ft^2 (5.4 lb ai/acre), 24 hour REI, and 2 day PHI. A maximum of 0.5lb ai/1000ft^2 (21.6 lb ai/acre) is allowed per cropping cycle (3). In 1997, 985 lbs benomyl were applied to 15.7% of California's mushroom acreage an average of 2 times at a median rate of 2.87 lbs/acre (1).

- Chlorothalonil – Label has a rate of 0.13-0.26 lb ai/1000ft^2 rate (5.7 – 11.3 lb ai/acre), 48 hour REI, and 5 day PHI. A maximum of 0.39 lb ai/1000ft^2 (17.0 lb ai/acre) is allowed per cropping cycle (3). In 1997, 3 lbs chlorothalonil were applied to 0.08% of California's mushroom acreage an average of 1 times at a median rate of 6.2 lb/acre (1).

- Thiabendazole – Label has a rate of 0.24 lb ai/1000ft^2 (10.4 lb ai/acre), 12 hour REI, and 12 hour PHI. A maximum of 0.6 lb ai/1000ft^2 (26.1 lb ai/acre) is allowed per cropping cycle (3). In 1997, 322 lbs thiabendazole was applied to 53% of California's mushroom structures an average of 3 times at a median rate of 5.35 lb ai/acre. An additional 1162 lbs of thiabendazole were applied to 9% of California's mushroom acreage at an average of 1 time at a median rate of 3.7 lbs/acre (1).

Bacterial and Virus Diseases

Bacterial brown blotch and ginger blotch - *Pseudomonas spp.*

Superficial brown or ginger colored lesions on the mushroom cap surfaces result in unmarketable mushrooms.

Bacterial Pit, Bacterial Slime Diseases - various bacterial spp.

Bacteria, at times in combination with fungal species, start as surface blemishes then develop as sunken pits of digested mushroom cap tissue or a slimy surface coating, making mushrooms unmarketable.

Bacterial Mummy Disease – *Pseudomonas spp.*

Crop may be delayed and/or reduced, with misshapen mushroom caps which, if left on the trays, shrivel and dry.

Virus Diseases - caused by several size classes of dsRNA (double-stranded RNA) viruses and potentially a bacilliform ssRNA virus (single-stranded RNA). Recently a disease known as "bare patch" has been associated with other RNA viruses. Crop symptoms include deformities of mushroom caps, crop delay, and areas of no production.

Control:

Non-chemical:
General sanitation and farm hygiene, control of insect vectors are used.

Chemical:
General disinfection using calcium or sodium hypochlorite, chlorine dioxide and other sanitizers. Wood trays or shelves are cleaned and pasteurized if possible.

NOTE: For the above fungal and bacterial diseases, crop damage may not be restricted to mushrooms pre-harvest on the trays. In many cases, post-harvest shelf life quality may also be affected.

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References

1. Annual Pesticide Use Report Indexed by Commodity, 1997. California Department of Pesticide Regulation.

2. California Vegetable Crop Statistics 1997. California Vegetable Review, Agricultural Statistical Service, California 1998. http://www.nass.usda.gov/ca

3. Crop Protection Reference, 15th edition. 1999. C & P Press.

4. California County Agriculture Commissioner Data, 1997
