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PROPAGATION OF HYDROPONICALLY-GROWN LETTUCE

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Abstract. Hydroponically-grown Butterhead-type lettuce is propagated from pelleted seed. Cultivars are selected for superior growth and yield under the environmental conditions available as well as the marketability of the finished product. Seed is sown in mineral wool starter cubes and germinated in a dark, temperature and humidity-controlled chamber. Seedlings are grown under supplemental light until large enough to transplant to gutters where they are grown to harvestable size. The nutrient film technique (NFT) of hydroponics is employed during the grow-out phase.

INTRODUCTION

After a year of pilot production in about 5,000 square meters of greenhouse, the Weyerhaeuser Company entered commercial production of hydroponically-grown lettuce in October, 1984. About three hectares of double-poly greenhouses in central Virginia produce five to seven million heads of Butterhead-type lettuce annually. Known as Waterfield Farms, the facility is located within 300 kilometers of several major population centers including Washington, D.C., Baltimore, and Philadelphia.

[1] Waterfield Farms is a division of the Weyerhaeuser Company, Tacoma, Washington, 98477

The process uses the nutrient film technique (NFT) in which the roots are continuously wetted by a flowing film of nutrient solution (1).

PRODUCTION FACILITY

A single 27,000 square meter greenhouse is sub-divided into 112 bays: three for propagation, twelve for juvenile growth, 95 for growing-out to harvest, and two "transport" bays for crop movement. Each grow-out bay has a capacity for about 5,500 heads. The roof sections are air-inflated, double-layer polyethylene, and the walls are 16 mm doublewall acrylic panels. Cooling is provided by exhaust fans located along each sidewall and inlet vents along the central ridge of the facility. The maximum air exchange rate is one per minute. Fog and mist cooling are used during periods when the temperatures exceed 28°C. or the relative humidity drops below 60%.

The fifteen propagation and juvenile growth bays are illuminated by sodium vapor lamps. The lamps provide about 100 $\mu Mm^{-2}s^{-1}$ (approximately 700 foot-candles) of supplemental light.

Liquid carbon dioxide is injected during daylight hours to maintain 1,000 ppm whenever the vents are less than 15% open.

On-site wells provide the daily need of 40,000 liters of water.

A unique feature is the heating method. A recompression station for a transcontinental natural-gas pipeline is located half a kilometer away. Water from heat exchangers in the compressor engine exhaust is piped to the greenhouse where it is circulated through the concrete floor and back to the compressor station. It is no coincidence that the demand for greenhouse heating corresponds with demand for natural gas in the populous northeastern United States.

About 3,000 m^2 of attached "headhouse" supports sowing, transplanting, solution preparation, harvesting, packing, shipping, storage, and mechanical systems.

CULTIVAR SELECTION

In the United States, by far the most common lettuce is variously called 'Crisphead' or 'Iceberg' lettuce. Field-grown on large acreage, mostly in California and Arizona, this cultivar ships well to domestic and foreign markets. Commercial quantities are not commonly grown in greenhouses in the United States and none, to our knowledge, hydroponically.

Romaine or cos lettuces are probably second in popularity and, like Iceberg, are predominantly field-grown.

Leaf lettuces, both in green and red cultivars, are enjoying increased popularity, possibly enhanced by the increasing popularity of salad bars. Some cultivars do well in hydroponic production but often are slower growing, require more space, and have a tendency toward necrosis of the leaf margins (tip burn) in greenhouse environments. Their high center of gravity sometimes causes toppling in hydroponic systems where the roots are not firmly anchored.

Butterhead types are well suited for hydroponic growing. They are popular as salad and sandwich greens and as bedding for cold appetizers and entrees. Their low, compact form lends stability in soilless culture. The mature heads handle, pack, and ship well with little damage.

The Dutch are recognized experts in breeding vegetables for greenhouse growing. They have done a remarkable job of introducing lettuce cultivars well suited to hydroponic production (2). Form, color, taste, and shelflife after purchase are selection factors especially important to the consumer. Handling characteristics and storage life are factors important to the shipper, wholesaler, and retailer. Yield, growth rate, space requirements, disease resistance, tolerance to environmental extremes, and resistance to premature bolting are among the selection factors important to the grower (4).

Dutch cultivars are selected which have proven best for the particular time of year. For winter production 'Salina' is particularly well suited. For spring and summer 'Sitonia' is more tolerant to high temperatures, higher light, and longer days without injury or bolting. 'Ostinata' is tolerant to a wide range of conditions and is the cultivar of choice for year-round production.

SEED

Untreated seed, having a minimum germination value of 90%, is purchased from United States distributors of Dutch breeder/producers. Shipment is made directly from the seed supplier to a processor in California where it is coated with a hard, spherical pellet of about 4 to 5 mm diameter.

The principal advantage of pelletizing is to simplify the sowing process. Pelleted seed is protected from mechanical injury, easily singulated, and readily handled by a variety of precision seeders including vacuum seeders. The size, color, and shape makes inspection of sowing quality much easier.

Pelletized seed costs almost twice that of raw seed, and there is the potential for impeding germination by oxygen deprivation or by physically interfering with emergence (5). The processor claims, however, that germination and emergence is actually enhanced by the pelletizing process. Production performance tends to support these claims. The details of seed pelletizing are proprietary to the processor, but it is known that soaking in a solution of kinetin enhances lettuce seed germination at elevated temperatures (6).

Soaking for several hours in 0.5% thiourea solution and stratification at low temperature may also overcome high temperature inhibition of lettuce seed germination (3.)

Oxygen deprivation is minimized by compounding the mineral coating in such a way that the pellet splits open upon imbibing water, thus exposing the seed prior to germination (5).

A fungicide, such as Thiram, is incorporated to counteract potential seed diseases.

PRODUCTION SEQUENCE

The process starts with the mechanical sowing of pelletized seed into mineral wool starter cubes. A Hamilton seeder places one pelletized seed into the dimpled cavity of each starter cube with greater than 90% accuracy. Cubes are in units of 200, 25 mm on center and 30 mm thick. Each unit is contained in a 0.3 × 0.6 m nursery flat and 21 flats fill a 2 m × 2 m ABS flood tray. An oversow factor of about 20% allows for fall-down during propagation and culling during transplanting.

The trays are watered to capacity and placed in a dark germination chamber for two or three days. The humidity is close to 100% and the temperature is maintained at 18 to 21°C. Upon leaving the germinator, the pellets have split and softened.

The trays are then placed in the propagation area in rail-supported, castered frames holding two trays. They are covered with plastic netting to discourage birds and rodents that invariably find their way into the house. Residence time in propagation is ten days (14 in winter) during which the seedlings are sub-irrigated with nutrient solution. Temperatures are held as close as possible to 25°C. Supplemental lighting is provided from 4:00 p.m. to 4:00 a.m. from 1 October to mid-February, and on cloudy days when the ambient light drops below 170 $\mu Mm^{-2}s^{-1}$ (about 1200 foot-candles).

After several true leaves have formed, the starter cubes are separated and respaced. A special "juvenile" tray with cavities, 60 mm on center, holds the starter cubes. The trays are white on top to reflect light and heat, and black on the underside to block out light, thus discouraging algae. The seedlings are sub-irrigated with a dilute nutrient solution via 5 mm slots in each cavity.

When the seedlings are about 50 mm in diameter, the movable tables are returned to the headhouse for transplanting.

Management of the propagation, juvenile, and transplanting operations is most critical. Weak or damaged seedlings become source-points for a variety of infections that can then spread to the surrounding crop. Thus, about 10–20% of the starter blocks are culled out during juvenile respacing and transplanting. The remaining vigorous seedlings are transplanted to 2 × 4 m growing frames with gutters spaced 180 mm on center. A perforated ABS cover provides support for the individual plants. Filled growing frames are conveyed to their appropriate location on rails down and across the house.

A modified Hoaglund's nutrient solution is prepared in a battery of mix tanks from which it is pumped to distribution headers along each row of gutters. Excess solution is collected, strained, and returned to the reservoir tank. The addition of make-up water and nutrients is automatically controlled.

Residence time on the growing tables varies with the season from three weeks in the summer to six weeks mid-winter. Crops are started in such a way as to maintain a nearly constant daily production.

The frames of finished crop are returned to the headhouse packing area. The covers, now holding the mature heads, are separated from the gutters. The heads are cut from the root cube, sorted, graded, individually packaged, and packed into corrugated shipping containers. Cases of lettuce are rapidly cooled in a vacuum cooler and loaded into refrigerated trucks for delivery, usually to wholesale warehouses or the distribution warehouses of major grocery chains.

The gutters and covers are thoroughly cleaned and sterilized with scalding water and chlorine solution in preparation for the next crop of transplants.

SUMMARY

There are several keys to satisfactory germination of lettuce seed for commercial hydroponic production. These may apply as well to greenhouse soil culture using transplants.

Cultivar Selection: Select cultivars of proven performance under local conditions. Run small test crops before making a major commitment.

Seed Quality: Purchase only pretested and certified seed from reliable suppliers.

Pretreatment: While substantially increasing seed costs, pelletizing has shown overall benefits.

Propagation Environment: Within practical limits, control light, temperature, and ventilation to near optimum. Be alert to nutrient stress and predation by insects, birds, rodents, or disease.

Sanitation: While it is difficult to maintain a sanitized workplace, a dedicated effort must be made toward that end. *Botrytis*, *Cercospora* leaf spot, *Pythium*, and *Rhizoctonia* have occurred when hygiene practices are below standard. Removing all plant debris—leaves, roots, dead plants, even dried algae—is essential since all of these tissues provide food sources for fungal and bacterial growth.

Profitable production depends heavily on good seed and careful attention to the propagation phase.

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1987 NEW ZEALAND PLANT VARIETY RIGHTS ACT

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Recent legislation has been introduced in New Zealand for the further protection of new plant varieties. The legislation, under the name of the 1987 PLANT VARIETY RIGHTS ACT, is along similar lines of other intellectual property acts for patents, designs, and trade marks.

That Plant Variety Rights are viewed in the same manner (in legislation at least) as patents, is important in a commercial atmosphere. New plant varieties should be viewed as any other product, the development of which incorporates a large amount of time, effort and money. As with new products it is essential that the developer recovers his investment by obtaining sole rights to the production, marketing, and licencing of the product and, perhaps, obtaining a trade mark for the product.

There are of course differences between plants and "standard inventions". Standard inventions do not reproduce themselves, nor do they continually produce saleable merchandise (e.g. fruit, flowers). It is because of these differences that a separate act was

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