Production & Marketing Reports

Rowcovers and High Tunnels Enhance Crop Production in the Northeastern United States

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PLASTICULTURE

Additional index words. intensive production, greenhouses, season extension, marketing, economics

Summary. **Crop growth is enhanced with the use of relatively inexpensive rowcovers and high tunnels. Even though these structures do not provide the same degree of environmental control as greenhouses, they modify the climate sufficiently to lengthen the growing season from 1 to 4 weeks in the spring and 2 to 8 weeks in the fall. Rowcovers generally remain over a crop for 2 to 4 weeks, whereas a high tunnel may function for an entire growing season. Both systems require a relatively low capital investment, provide a good return on investment, and improve the ability of new growers to succeed in the crop production business. The selection of either rowcovers or high tunnels will depend on the management program of a grower; however, both growing systems potentially are economically viable means of season extension.**

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Scientific contribution no. 1789 from the New Hampshire Agricultural Experiment Station.

Protected agriculture using specialized structures has its roots in Roman agriculture and subsequent European plant-growing enterprises (Dab-ymple, 1973). Since those early beginnings, a multitude of structural types and systems have been used to modify the environment. Conceptually, they all incorporate the function of a modern-day greenhouse, which is the most common form of protected agriculture in the United States. Typically, the greenhouse structure has a permanent heating and ventilation system, is electrically powered, and provides for year-round production. Alternative protected growing systems are rowcovers and high tunnels, neither of which has mechanically assisted heating or ventilation features. Both systems are used primarily for season extension in spring or fall or both. More precise definitions for each are:

Rowcover A flexible, transparent material (polyethylene, polyester, or polypropylene) that is hoop-supported or floated over a row or rows of crops at planting (seeds or transplants). It remains on the crop for 2 to 4 weeks in the spring or longer in the fall or winter. Hoop-supported rowcovers also are known as low tunnels.

High tunnel A portable walk-in, greenhouse-like structure without a permanent electrically powered heating or ventilation system, covered with one layer of plastic, and sited on field soil. In the northern United States, use is primarily seasonal from early spring to fall. Winter use is quite feasible in areas with moderate climates.

While greenhouses may offer somewhat precise environmental control (at a high price), rowcovers and high tunnels are not nearly as precise and not nearly so expensive per unit of area. They are not intended to function the same as greenhouses. They are intended to ameliorate adverse environmental conditions and offer some control of insects, diseases, and wildlife. Additionally, rowcovers and high tunnels should be considered as tools in an overall management program encompassing mulches, soil type and typography, cultivars, environmental considerations, pests, marketing, and grower objectives. The low capital investment associated with these systems is especially important to new growers.

ROWCOVERS

A brief history of rowcovers has been reported (Wells and Loy, 1985). Worldwide use of rowcovers has grown dramatically as new types of materials have been developed and as new uses have been found (Jensen, 1988; Takakura, 1988) from the traditional hot tent to heated, air-supported systems (Jensen, 1966). From the outset, it should be emphasized that the primary function of rowcovers in most cases is not frost protection; rather, they serve to enhance growth during periods of low ambient temperature. For most rowcovers in use today, the maximum frost protection in the spring is 3 to 4F (2 to 3C) below ambient freezing temperature. Only with specialized, heavyweight covers is greater frost protection achieved.

Types of rowcovers

Paper. Early research involved translucent paper. In fact, celery growers have used paper rowcovers, but other materials essentially have replaced paper.

Polyethylene. Most polyethylene covers are 18 to 26 µm thick and are solid, slitted, or perforated. When solid covers are used, two 3-foot-wide pieces of plastic are supported with wire hoops and a wire running over the tops of the hoops. The lower edges of the cover are secured with soil and the two top edges are joined at the center wire and secured with common spring-loaded clothespins. To facilitate daytime ventilation, the cover is opened each morning by removing the clothespins. To conserve heat during the night, the covers are closed in early evening (Hall and Besemer, 1972). A major disadvantage of this system is the high labor requirement for daily ventilation and the risk of the covers blowing apart at night during gusty winds.

A variation on the theme was devised by Loy and Wells (1982) so that daily opening and closing could be eliminated. Using the concept of slit-film mulch (Smith, 1973), a slitted rowcover of one 6-foot-wide sheet of clear plastic was developed. The slits are 5 inches long, 0.75 inches apart, and are configured in two rows of slits 2 feet apart. Once the cover is in place over wire hoops, the cover is not manipulated in anyway until removal 2 to 4 weeks later. In a fictional sense, the slitted cover is a compromise between labor reduction (opening and closing of solid covers) and greater heat loss at night through the slits than through a solid cover.

Perforated covers typically have seventy-five $^3/_8$-inch holes/ft^2 (eight hundred 9.5-mm holes/m^2). These covers are either hoop-supported or are used in a floating mode directly over plants. They provide a warmer air environment during the day than slitted covers, but provide about the same amount of nighttime heat retention. Perforated covers are available as wide covers, up to 50 feet (17 m) wide and 3000 feet (900 m) long.

Polyester and polypropylene. The chemistry of these two covers are different, but the final usable products are very similar. The material of each is a spunbonded, lightweight fabric that is 0.5 to 0.6 oz/yd^2 (17 to 20 g/m^2) for most uses, although the weight varies from 0.3 to 1.50oz/yd^2(10 to 50 g/m^2) for specialized uses such as insect control with the lighter weight and frost protection with the heavier weight. The spunbonded feature (as opposed to woven) permits the deposition of small-diameter fibers into a fairly uniform fabric sheet, allowing for 80% light transmission as well as air and water permeability. These covers are ultraviolet (UV) -light-stabilized to prevent premature degradation under agricultural environments. Covers are available in widths from 6 to 50 feet (1.8 to 17 m). Regardless of width and whether the grower is covering a single row or multiple rows, these lightweight spunbonded covers are secured only along the edges, usually with soil. Therefore, the wider the cover, the less labor-intensive the installation. For example, a 40-foot cover is installed almost as quickly as a 20-foot cover.

Uses of rowcovers environmental modification

Temperature. Because rowcovers are used to extend the season, night temperature is frequently the focal point for temperature control. However, as discussed above, major frost protection is not feasible with these lightweight covers; only 3 to 4F protection can be expected. The exception is with the 1.5 oz/ft^2 (50 g/m) material, which is heavy enough to provide greater frost protection but is too thick to allow adequate light transmission; hence, early morning removal is necessary. However, there has been a recent introduction of a 1.25 -oz/yd^2 (42-g/m) polypropylene that improves heat retention, yet allows 75% light transmission. The major benefit is realized as the temperature rises faster than the ambient temperature in the morning under covers (Wells and Loy, 1985) and is maintained longer in the afternoon. Because covers are left in place for 2 to 4 weeks, the daily accumulation of additional heat units contributes directly to enhanced growth. However, the downside of accumulated heat is excessively high temperatures under covers when ambient temperatures exceed 86F (30C). The blossoms of solanaceous crops are particularly sensitive to temperatures of this magnitude (Wolfe et al., 1989), whereas blossoms of cucurbits are more tolerant of high temperature.

Not only are the high and low temperatures affected by covers, but, apparently, they can moderate low temperature extremes in the soil. Seedlings of overwintering lettuce (seeded in the fill) were heaved out of the soil with alternate freezing and thawing while covered seedlings were not heaved or killed by winter temperatures at 0F (18C) (O.S.W., unpublished data).

Extension of the season in the fall is accentuated by covers because of the enormous amount of heat stored in the soil as compared to springtime soil heat accumulation. A single layer of spunbonded cover will protect mature pepper and tomato fruits from freezing temperatures down to about 25F (-4C), which is more than twice the protection afforded by covers in the spring.

Wind protection. Spunbonded rowcovers increased the growth of cucumber by reducing the windspeed under the cover (Schloupt et al., 1991). When covers are supported by hoops, plants are protected from wind, blowing sand, and dessication. It should be pointed out, however, that floating covers may damage the tender growing point of plants under extremely windy conditions. When such conditions prevail, the cover, whether narrow or wide, should be supported over the plants with hoops or other devices.

Rain protection. Hoop-supported covers shield plants ii-em direct hits by rain droplets during stormy conditions. Even though the water penetrates the covers, the plants are protected from the sheer physical force of the rain. Because polyester and polypropylene do not absorb water, these covers do not become excessively heavy during rain or irrigation and, consequently, do not damage plants even though the cover is lying directly on the plants.

Pest protection. Spunbonded covers protect against some insects and insect-transmitted diseases by providing a barrier between the insects and the crop (Duchesne, 1990; Hemphill, 1989; Hough-Goldstein, 1987; Natwick and Durazo, 1985; Wells and Loy, 1985). A cover should not be used where there is the likelihood of overwintering insects emerging from the soil under the cover. Because of the favorable environment provided by the cover, the end result could be a serious insect problem before the insects are noticed. The under-cover environment is also very conducive to weeds. Without mulch or herbicides, weeds quickly proliferate and seriously compete with the crop. Even with herbicides, a higher application rate is needed to control completely the weeds that normally are controlled at a lower rate without a cover.

Economics of rowcover use

The number of variables associated with rowcover use are numerous; therefore, the individual user will need to workout the management and economics in light of the objectives of the farm or other growing unit. The average costs for cover alone are $500 (polyethylene) to $800/acre (spunbonded) ($1200 to $2000/ha). The cost of labor for installation varies widely depending on whether single rowcovers with supporting hoops are used or wide floating covers are applied. With earlier crop maturity, a longer market window is provided, usually at favorable prices. Also, the cost of the cover per crop can be reduced by using the cover either on multiple crops in one season or on the same crop over two to three seasons with careful handling. Probably the greatest deterrent to extended use of spunbonded covers is the weakening of the fabric and tearing during handling. High yields and early maturity are results of enhanced growth; when these are combined with better marketing opportunities, the added benefits of covers may be determined.

HIGH TUNNELS

High tunnels fit into a crop management program somewhere between low tunnels (single rows with a rowcover) and greenhouses. They look like greenhouses and incorporate the basic concepts of a greenhouse, yet the management differs considerably. Whereas greenhouses are geared toward year-round production, tunnels are intended for season extension. High tunnels are easily portable in the sense of fast take-down and set-up, which is important for crop rotation. The basic features of a high tunnel as used in New England are as follows (Wells, 1991 b):

- A 14 x96-foot (4.3 **x29-m)** quonset style, metal- bow tunnel is a standard unit.
- The bows are attached to metal posts (3.5 feet or 1.1 m long), which are then driven into the ground 2 feet (0.6 m).
- The end walls are detachable or have doors large enough to accommodate a small tractor with tillage equipment.
- The plastic cover is 6-mil greenhouse-grade polyethylene.
- Trickle irrigation lines are laid, one line per row.
- The soil and the trickle irrigation lines are covered with a sheet of 6-roil black plastic.
- Ventilation is provided by roll-up sides using a sliding T handle (Fig. 1).

The use of tunnels for food crop production in the United States is very limited. (However, high tunnels, generally called hoop houses, are used commonly for the overwintering of nursery stock.) In contrast, southern Europe, Asia, and Israel use high tunnels extensively. A cursory glance from the air in the Mediterranean region reveals hundreds of hectares of tunnels in concentrated locations. Despite the low use of high tunnels in the United States, research in New England indicates that these structures have a high potential for meshing into integrated, intensive production of food crops (Gent, 1991; Wells, 1991a, 1992). This is especially true where direct selling is the primary marketing chain nel.

High-value crops such as tomato, pepper, cucumber, melon, summer squash, and cut flowers are suited ideally for high-tunnel production. Gent (1991) found that high tunnels extended the production season of tomato by accelerating growth and ripening. Pepper ripening also was advanced, but less than that of tomato. High tunnels in New Hampshire advanced maturity of tomatoes by 32 days compared to unprotected field tomatoes (Wells, 1991 b). In looking at the economic feasibility of producing tomatoes in high tunnels, Wells and Sciabarrasi (1991) calculated that the net return (after *all* expenses) for tomatoes was $0.71/lb based on the production of 2000 lb in a 14 × 96-foot tunnel and at a retail selling price of $1.60/lb.

High tunnels are relatively inexpensive. Using 1991 figures, it cost $1.26/ft^2 ($13.56/m^2)of growing area to erect a 14 × 96-foot (4.3 × 29-m) high tunnel, including labor costs. Because of the low capital investment and high returns, high tunnels provide a practical means of entry into intensive crop production for new growers or others with limited capital assets. Unlike some greenhouses, high tunnels do not qualify as taxable structures.

Overall, a high tunnel is a growing structure that protects against rain, wind, weeds, some insects, and diseases. Not only are high tunnels useful for early spring/late fall growing, they are useful all summer long. With daily attention to ventilation (rolling up the sides each morning and rolling them down each evening), the tunnel environment is very conducive to excellent crop growth. However, width is critical; when the tunnel is wider than 20 feet, it is doubtful that adequate ventilation is attainable when outside temperatures exceed 86F (30C). Length is not a factor in ventilation as long as the width is not excessive.

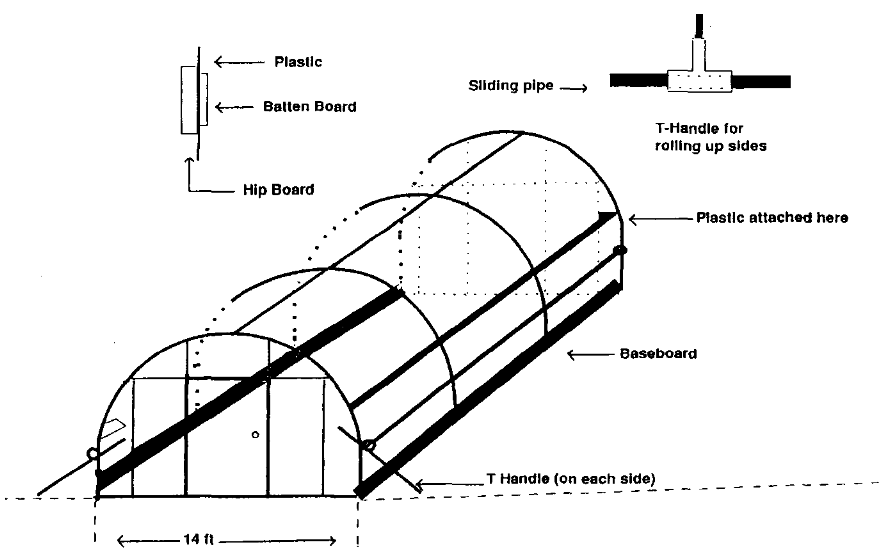

Fig. 1. *A high tunnel with roll-up sales for ventilation.*

Summary

Rowcovers and high tunnels are economical systems for enhancing crop growth, extending the season, and assisting growers in maximizing profits with intensive production practices. Based on grower adoption of rowcovers and high tunnels throughout the world, it seems reasonable to conclude that these production systems are integral to early production. High tunnel use in the United States is not nearly as prevalent as in other parts of the world, but, in the northeastern U.S., the interest in high tunnels is growing rapidly. For example, in New Hampshire in 1988, only 15 high tunnels were used for vegetable production; in 1992, there were about 80.

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