decrease in 1996 suggesting that the longevity of asparagus plantings in Florida may be considerably shorter than those in principal producing areas.

Average annual yields per acre in this trial ranged from 841 lb/acre for 'Syn 4-51' to 1530 lb/acre for 'Syn 4-MD10'. This is far below the annual average yields of 3633 lb/acre produced in Washington, 3000 lb/acre produced in California, and 2433 lb/ acre produced in New Jersey (U.S. Dept. Agr., 1996).

Greatest average spear weight and the highest proportion of very large and large spears were produced by the purple-colored variety 'Viola' for most of the experimental period. Spear weight was greatest in 1993, the second harvest season, and declined each year thereafter. This is another indication that asparagus planting longevity in Florida is relatively short.

Even though 'Viola' had the largest spears in this trial, only 2% were very large and 8% were large while 33% were medium, 31% small, and 26% very small. This can be contrasted with 'Syn 4-51' which had 61% of its spears in the very small size category (data not shown).

Based on the results of this trial, we do not believe that asparagus is a viable economic alternative crop for southern peninsular Florida. However, new varieties are being developed constantly so there may be some that are suitable for production here in the future.

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TRANSPLANTER MULCH HOLE BURNER WITH CYCLOIDAL MOTION

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Abstract. **The plant holes made in plastic mulch must be accurately spaced and properly formed so that the film does not tear nor are the seedling plants damaged from flags of plastic blowing in the wind. A desirable method of forming planting holes is to melt or burn the film with a hot dibble; the film is not torn and the perimeter of each hole is stress relieved and thickened, thereby less likely to tear.**

A slider crank mechanism has been employed to give a hot dibble, hole burner an appropriate cycloidal motion such that it contacts the plastic mulch to form holes at the desired interval and allows a cup wheel transplanter mechanism to set seedling plants.

Introduction

When Emmert (1956) started his pioneering work on plastic mulch culture, he thought that machines could be developed that would lay the film, plant or transplant seeds or seedlings through the plastic, and take the film up at the end of the season. Engineers and machine builders have met most of these needs, but some of the planting and transplanting equipment still need to be improved. When he planted beans, Emmert used a jab planter which made a slit in the film to allow the plants to emerge. Some of the equipment used today continues to form plant holes in this manner. This paper focuses on a new device that creates uniformly shaped and spaced holes into which seedlings can be transplanted.

Hayslip (1973) conducted early experiments with his "Plug-Mix" on plastic mulch-covered beds. His initial trials were with a hand-operated machine which cut holes through the plastic and deposited the mixture of seeds, peat, and vermiculite. Later a transplanting machine was adapted to mechanically place the mix through holes in the plastic. It was a modified cup wheel type of machine originally designed for transplanting seedlings grown in peat blocks. The holes punched by this transplanter created ragged pieces of plastic which beat on the emerging plants, and ragged holes caused tears to start in the film from blowing wind. As a solution to this problem, Florida growers developed a hole burner that melted holes in the plastic. The machine used an LPG-oxygen burner directed at the film to melt a hole. A shutter device controlled the exposure of the film to the flame. The advantages of melting holes were that the ragged flaps were eliminated and the film was thickened and stress relieved around the openings. However, because the shutter device moved along with the planter, elongated holes resulted which were (usually) longer than necessary for the plant. A later development on plug-mix planters was the "*hot dibble*" which melted a hole and created a soil depression for the plug mix (Dubrucq, 1984). This device also made elongated holes because the cam operated dibble moved along with the planter. Some Japanese farmers use a small iron pot containing burning charcoal to make the holes for transplanting seedlings. They

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touch the film mulch with the bottom of the hand held pot quickly creating holes ready to accept plantings. Their hand movement approaches cycloidal motion.

Hole Formers for Transplanting Machines

A popular transplanting machine incorporates the "water wheel" which is a lugged wheel that punches holes in the plastic film and makes a dibble in the soil while water is applied simultaneously. The motion of each lug on a water wheel is such that it penetrates almost vertically through the mulch into the soil. A hole only as large as the lug results since there is no relative movement between the wheel rim and the ground. In engineering terms, there are instant centers of rotation between points on the wheel rim and corresponding points on the ground. By combining the features of the lugged wheel and the hot dibble from the earlier plug mix planter or the Japanese charcoal heated dibble, a design using a rolling wheel with hot lugs to melt holes in the plastic might be desirable.

The path in space of a point on a rolling wheel is a cycloid, the desirable path of a hot dibble hole burner. A problem with developing this device is how to heat the dibble. If the heat source for the dibble were directly mounted on the wheel, the fuel would have to be transferred through the axle by means of a swivel connection. Using liquefied petroleum gas, (LPG) for example, could be difficult since any leak in the joint would be a safety hazard. A satisfactory locus for the hot dibble has been resolved but a mechanism is needed to satisfy the design constraints.

A slider crank mechanism (Fig. 1) with the hole burner attached to the connecter link near the crank pivot satisfies the design constraints. The plastic mulch hole spacing (S) is a function of the crank radius (r) or S = 2 π r. With this mechanism the hole spacing would be adjustable by making the crank radius adjustable. Since the connector link remains in a nearly vertical orientation without rotation, the fuel gas can be fed to the hole burner through a flexible hose without any swivel connection.

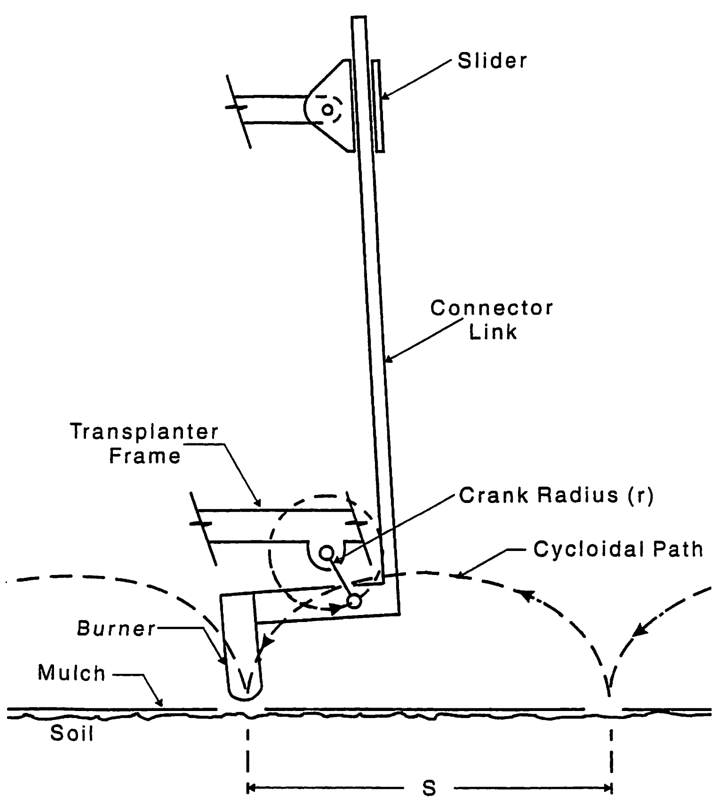

Figure 1. Burner on a slider crank mechanism.

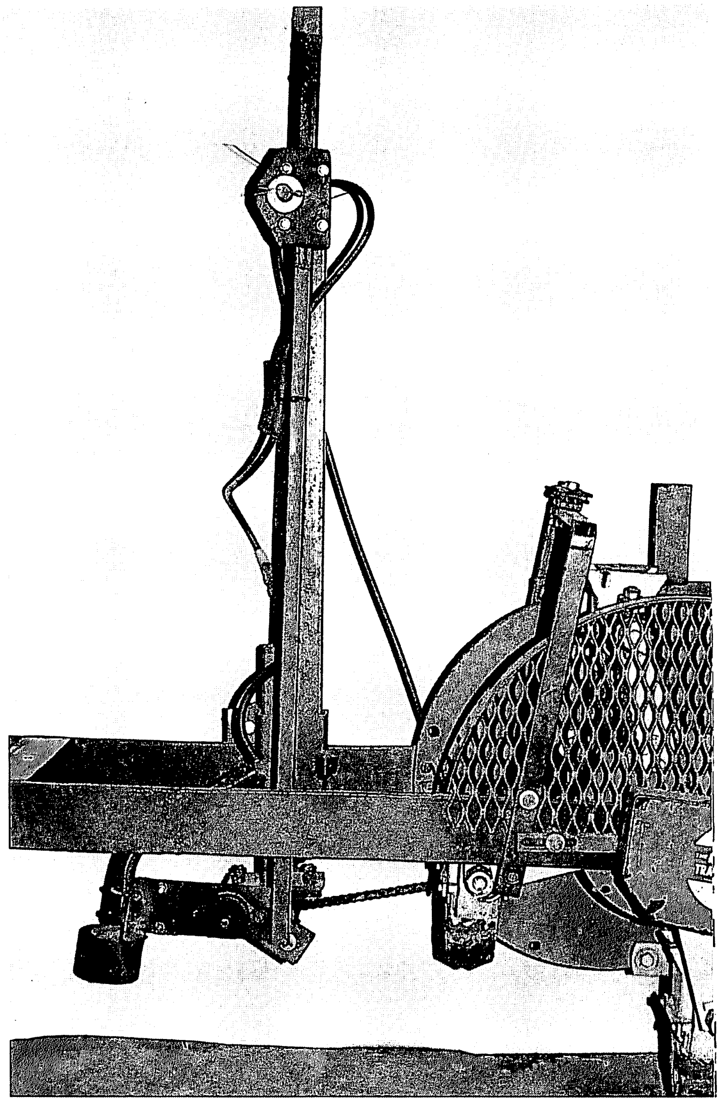

Figure 2. Transplanter with cycloidal hole burner.

A slider crank mechanism was designed and fabricated to carry a hot dibble type hole burner on a cup wheel type transplanting machine (Fig. 2) and adjusted to plant tomato (*Lycopersicon esculentum* Mill.) seedlings at a 41 cm (16 in.) in row spacing. This spacing required a crank radius of 6.47 cm (2.55 in.). The cup wheel transplanting machine was a Model 900 Mulch Planter with a lengthened frame manufactured by the Mechanical Transplanter Co. of Holland, MI.

Since the transplanter with the 41 cm. (16 in.) plant spacing carries four cups on the wheel, the hole burner mechanism must form four holes for every revolution of the transplanter wheel. The hole burner must also be synchronized with the cup wheel so the cups can target each of the preformed holes. These two requirements are accomplished with a roller timing chain drive from the cup wheel with a 1:4 drive ratio; causing the hole burner crank to turn four times

Table 1. Adjustment guide for hole burner on a Model 900 Mechanical Mulch Planter.

Cups	Plant spacing	Crank radius	Drive ratio
2	32 in (81 cm)	5.1 in (12.9 cm)	1:2
3	21 in (54 cm)	3.4 in (8.6 cm)	1:3
4	16 in (41 cm)	2.6 in (6.5 cm)	1:4
5	13 in (33 cm)	2.0 in (5.2 cm)	1:5

for each turn of the cup wheel. The position of the chain on the roller chain sprockets can be adjusted for precise timing adjustment of the hole burner and the transplanter wheel so that each cup accurately enters each preformed hole.

The in-row plant spacing on this transplanting machine can be changed by adding or removing seedling cups from the wheel. If the number of cups is changed from four, the burner crank radii and drive ratio must be adjusted accordingly. Table 1 gives the crank radii and drive ratios for each available plant spacing from 32.5 cm (12.8 in) to 81.3 cm (32 in.).

The speed of the hole burner mechanism is, of course, a function of the transplanting rate. A typical plant setting rate for a transplanter with one worker feeding the plants is about 1 to 1.5 plants per second. At this rate, the hole burner mechanism must turn at 60 to 90 rpm, an appropriate rotational speed for this mechanism without having to be dynamically balanced.

Field Performance

This mechanism has been field evaluated with a 7.6 cm (3 in.) cup dibble hole burner heated with a LPG burner. It has given satisfactory service while planting experimental plots. A modified mechanism with a 10 cm (4 in.) cup dibble burner has been installed on an automatic vegetable transplanter and has performed satisfactorily at a transplanting rate of over two seedlings per second.

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REDUCING ROOT-ZONE TEMPERATURE TO ENHANCE HEAT-TOLERANT TOMATO YIELD

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Abstract. **Studies were conducted for two years to determine the influence of deep transplanting, time of daily irrigation, and polyethylene mulch color on root-zone temperature and yield of two heat-tolerant tomato (*Lycopersicon esculentum* Mill.) cultivars. Five-week-old tomato transplants were planted to a depth of either 7.5 or 15.0 cm, irrigated every other day for 2.5 hours starting at either 7:30 AM or 2:30 PM for 80 days following transplanting, and mulched with white-surface (white on black) or black polyethylene. Soil temperatures were recorded daily at 4:00 PM for 21 days from the beginning of fruit set (two weeks following transplanting) until the tomato canopy shaded the mulch surface. Transplanting tomatoes to a depth of 15.0 cm significantly lowered soil temperature than at the 7.5 depth and increased the marketable yield in both years and the total yield in one year of this study. Fruit weight was not influenced by transplant depth, but plant dry weight was significantly increased by transplanting deeper in 1995. Morning irrigation and white-surface polyethylene mulch also significantly reduced soil temperature and increased the marketable and total yields and average fruit weight in both years and plant dry weight in 1995.**

The desire to extend the normal tomato growing season into the hot summer months by breeding heat tolerant tomatoes has received considerable attention in the past several years (Hanna and Hernandez, 1982; Hanna et al., 1982; Wessel-Beaver and Scott, 1992). As a result, several heat-tolerant cultivars and inbred lines were developed for producing tomatoes under these above-optimal temperature conditions (Hanna et al., 1992; Scott et al, 1995). Although these cultivars and inbred lines are genetically adapted to produce under high ambient temperatures using standard cultural practices, little is known concerning whether or not alternative cultural practices such as planting depth, the time of day irrigation is applied, or polyethylene mulch color might improve their root-zone environment and yield.

Information on the effects of planting depth on root-zone temperature and growth and yield of vegetable crops is limited. Lindgren (1990) found that asparagus (*Asparagus officinales* L.) spear emergence and spring harvest date were delayed

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