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# Development of a Foam Microenvironment for Enhanced Seedling Establishment

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***Abstract.*** **Seeds of tomato (*Lycopersicon esculentum* Mill.) were sown in the greenhouse in a field soil prone to crusting, and at the same time a stable foam was generated and placed over the seed furrow in a 4 × 0.5 cm band. The foam withstood a simulated rain and offered little (0.03 MPa) mechanical resistance to seedling emergence. The percentage of seedling emergence was increased by the foam microenvironment. The foam strip remained over the seed furrow for 3 weeks and was not observed to be phytotoxic to seedling growth.**

Seed quality and the seedbed environment, including both biotic and abiotic stresses, interact to determine final plant stand. Presowing treatments to improve seed quality and/or advance the germination process have been reviewed (6). Stand losses due to soil pathogens and insects can be reduced by pesticides, but there are few practical methods to alleviate abiotic stresses such as soil crusting from time of sowing to seedling emergence.

Mulches used routinely for turf establishment (2) have had little commercial acceptance for row crops. Vermiculite, perlite, and peat have been used to enhance field establishment of several vegetable crops (5, 8). Major disadvantages for wide scale application of these materials are: 1) cost, and 2) the large bulk of physical material required.

Foam has been used in agriculture as a carrier for pesticides and frost control (1). These foam systems contain 3 ingredients: a gas, a liquid, and a foaming agent. The foaming agent is diluted with water and then mixed with air. A hydrolyzed protein has been used as the foaming agent for frost control and will produce a foam that will remain about 12 hr (3). The effectiveness of the foam has been shown to be dependent on the synoptic situation which produced the frost.

This paper describes a method to manufacture a stable foam in the field to be placed over the furrow at time of seeding. The purpose of the foam is to improve the microenvironment for seedling establishment. Other desired properties of the foam include: 1) ability to withstand rain-drop impact, 2) to remain intact for a 2- to 3-week period after sowing, and 3) nonphytotoxicity.

*Apparatus for foam production.* The schematic for the *in situ* production of foam is shown (Fig. 1). Lines on the schematic are 9.5-mm rubber hoses capable of withstanding 1.0 MPa. Two 11-liter containers served as reservoirs for the resin and foaming agent. Air pressure (<0.45 MPa) propels the solutions to the metering gun.

Three flowmeters (air 4–28 liters min$^{-1}$ and resin and foaming agent 0.1–1.0 liters min$^{-1}$, Cal Q Flo Blue White Ind., Westminster, CA 92683) quantified flow rates of the 3 ingredients. In-line, 100-mesh strainers (not shown) were placed between the reservoir tanks and flow meters to remove particulate matter.

The foam gun or metering gun (C.P. Chemical Co., White Plains, NY 10606), originally designed for home and industrial thermal insulation, was modified for our work. The foam volume output was reduced from 110 to 6.5 liters min$^{-1}$. The volume of the foaming chamber was reduced from 0.05 to 0.015 liters and the spray tips for both liquids delivered 9.5 liters hr$^{-1}$. The foam spreader was 4-cm-wide and 0.5-cm-high, and was connected from the output of the metering gun by a 75 cm × 12.6 mm plastic tube.

*Preparation of the foaming agent with catalyst.* The foaming agent with catalyst was produced by mixing 1 liter of water, 60 ml of 40% concentrate dibutylnaphthalenesulfonic acid (DBNA) (C.P. Chemical Co., White Plains, NY 10606), and 4 ml of concentrated phosphoric acid. The mixture may be stored for prolonged periods at room temperature. The DBNA and $H_3PO_4$ are the foaming agent and catalyst, respectively.

*Preparation of resin.* A solution of methylene diurea (C.P. Chemical Co., White Plains, NY 10606) was used as the resin. The solution contained 40% solids and was manufactured with a urea to formaldehyde ratio of 1.0 : 1.2. The stock solution was refrigerated (5°C) for prolonged storage. The solution, prior to use, was allowed to equilibrate to room temperature and filtered through an 80-mesh strainer.

*Production of foam.* The foam was manufactured within the metering gun by first mixing air with the foaming agent and then spraying the resin onto the freshly formed foam (6.5 liters min$^{-1}$ of air, 88 ml min$^{-1}$ of foaming agent and catalyst, and 72 ml min$^{-1}$ of resin). The reactants were maintained between 15 and 30°C to achieve proper mixing and foam properties. Some mixing did occur in the plastic tubing and thus its length does affect the finished product.

The foaming agent and air produced an unstable foam with a foam fineness or bubble size of about 0.2 mm. The resin, when sprayed, coated the freshly formed foam. The $H_3PO_4$ catalyzed the polymerization of the

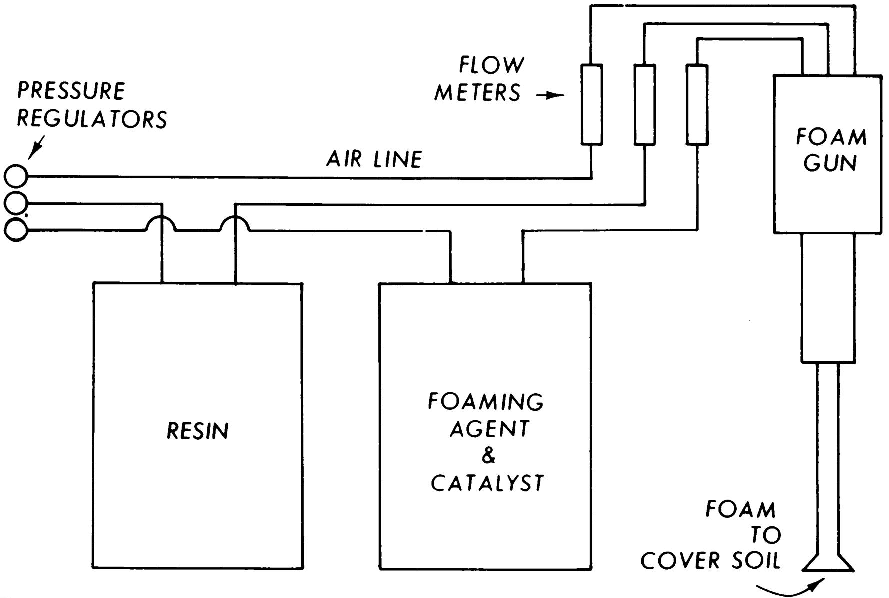

Fig. 1. A schematic for the production of foam.

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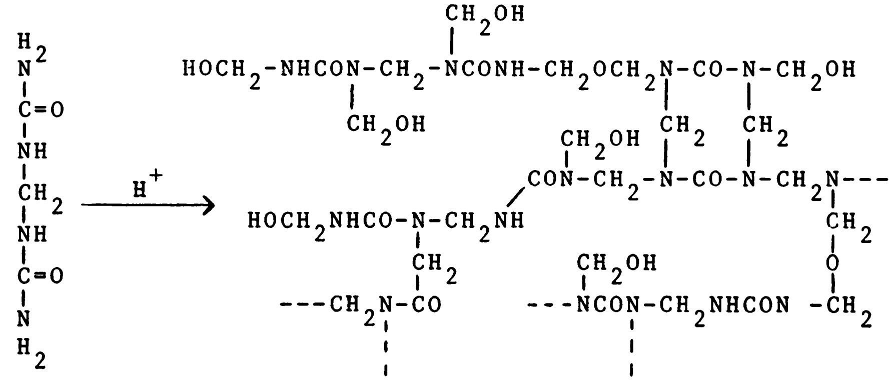

Fig. 2. The polymerization of methylene diurea by an acid catalyst.

resin. The polymerization of methylene diurea by an acid catalyst is shown (Fig. 2). The methylene diurea condensation product was crosslinked by methylene bridges (4). This polymer was water-insoluble and maintained the foam structure and integrity.

One technical difficulty has been encountered during the production of foam. The metering gun, plastic tubing, and/or foam spreader sometimes became plugged by polymerization of the resin. When this occurred, the gun was partially disassembled and cleaned with hot water before foam production could resume. This plugging problem will have to be solved before the technique can be used commercially.

*Seedling emergence study.* A greenhouse experiment was conducted to evaluate the effect of the foam microenvironment on seedling establishment. A diurnal temperature of 20°C (day), 15° (night) was maintained. Seeds were sown on a bench filled with 18 cm of a Lima silt loam soil obtained near Geneva, N.Y.

'Heinz 1350' tomato seeds were sown 1.5 cm deep in the soil in 1-m rows. There were 100 seeds per row with 4 replications per treatment in a randomized complete block design.

The treatments included: 1) control, 2) vermiculite, and 3) foam. The control contained seeds covered with soil in a conventional manner. Number 3-grade horticultural vermiculite was applied over the seeds at 200 cc $m^{-1}$ of row and then lightly covered (>5 mm) with soil. Foam was generated as previously described and was placed over the furrow in a 4 × 0.5 cm band. The material was extruded at 200 cc $m^{-1}$, and the edges of the foam were covered with soil. The consistency of the freshly produced foam was similar to a heavy whipping cream. The foam cured within minutes and resembled the texture of sponge cake.

Rain was simulated over the experiment one day after the treatments were sown. Two 3.8 liters $min^{-1}$ flat fan sprayers applied 1 cm of water over the bench. The soil was allowed to dry for 14 days and then rewatered periodically after this period for the remainder of the emergence period.

Seedling emergence and soil resistance were recorded at 14 and 25 days after planting. The soil mechanical resistance was measured by a Chatillon Gauge R penetrometer (John Chatillon and Sons, Kew Gardens, NY 11415) to a depth of 1 cm. The penetrometer readings in grams were converted to MPa by the following equation:

$$\text{MPa} = \text{penetrometer force (g)}/1.0 \times 10^{-2}\ \text{g/cm}^2 \times \text{cross-sectional area of penetrometer tip (cm}^2\text{)}$$

The simulated rain and subsequent waterings did not appear to disturb the integrity of the foam. The hydrophobic foam repelled water and prevented soil erosion. The force required to penetrate the foam was 0.03 MPa (Table 1). The foam system withstood water and water-drop impact but had little mechanical resistance to seedling emergence.

A soil crust of 1.0 MPa developed after 14 days (Table 1). Rewatering decreased the crust strength in the control. Both foam and vermiculite acted as anticrustants. Seedling emergence was enhanced by the foam microenvironment. The foam remained intact throughout the length of the study, and no phytotoxicity was observed on seedling growth.

An earlier study has shown that a urea formaldehyde foam 'Hygromull' improved germination of grass seeds under saline conditions (7). In contrast to our application of a freshly produced foam, the foam used in the earlier work was dried and shredded prior to use. The texture of the product was similar to a coarse vermiculite.

The density of our freshly produced foam was 30 kg $m^{-3}$. The fact that the foam was composed of 97% air indicates that a small volume of liquid can be generated into a large volume of foam.

The quantity of foaming agent and resin solutions required per ha are 24 and 20 liters, respectively. This can be compared with 2.2 $m^3$ of vermiculite. The cost per ha of the combined ingredients for foam production and vermiculite are $25 and $75, respectively. This comparison was based on an extrusion rate of 0.2 liters of material per meter of row and a row spacing of 0.9 m.

Table 1. The percentage of emergence and mechanical resistance in MPa of tomato 'Heinz 1350' seeds covered with soil, vermiculite, and foam.

| | Emergence % | | Mechanical resistance (MPa) | |
|---|---|---|---|---|
| Treatment | 14 days | 25 days | 14 days | 25 days |
| Control | 38 b$^z$ | 71 b | 1.00 a | 0.44 a |
| Vermiculite | 56 ab | 85 ab | 0.13 b | 0.11 b |
| Foam | 76 a | 95 a | 0.03 b | 0.03 b |

$^z$Mean separation within columns by LSD, 5% level.

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