Project title: Design of a Field Raised-Bed Trough System for Strawberry Production in California

Type of proposal: Continuing

Funding Amount for 2009: $90,000

Year of project: Second

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Summary:

Strawberry production in California is facing increased scrutiny with the continued use of soil fumigation. In response to this situation, the California Strawberry Commission has established “Farming without fumigants” as a high research priority area. After a thorough review of fumigant-free production systems in the world, the industry identified an open field raised-bed trough system containing a pathogen free substrate as the most promising system for the California production environment. The lack of key information for open field strawberry fruit production in California requires both experimental research and production field testing. The lack of information on applicability of a field raised-bed trough system for use in California requires research to evaluate its technical feasibility and effectiveness in avoiding root diseases. Information is also lacking on design of these systems and the water and nutrient management required under this new production system where strawberry plants will have much reduced rhizosphere for water and nutrient uptake. Other concerns about the system include potential environmental impacts on surface and ground water quality due to possible runoff from the troughs and leaching in the underlying soil. The proposed project takes a multi-disciplinary system’s approach to develop and evaluate the technical feasibility and commercial suitability of the new production system for strawberry fruit growers, to give California growers sustainable fumigant-free options for long-term productivity.
Justification: California produces 88% of the strawberries grown in the U.S. Essentially all of the strawberry production is done on raised beds in open fields. California has developed into the leading strawberry fruit production region because of the development of pre-plant soil fumigation with methyl bromide: chloropicrin mixtures in the late 1950s and early 1960s. Prior to that time, Verticillium wilt and other soil-borne diseases prevented the development of the current annual raised-bed production system (Wilhelm and Paulus 1980). About 96% of strawberry fruit production fields in California are pre-plant fumigated with either methyl bromide or an alternative fumigant and this accounts for approximately 70% of fumigants used in California (Trout 2006).

The large strawberry acreage creates a demand that significantly exceeds the use limit imposed by the township caps and other regulatory restrictions on the use of alternative fumigants. Emerging regulatory restrictions will further limit the use of pre-plant fumigants in strawberry fruit production. Methyl bromide and its alternative fumigants are volatile organic compounds (VOCs) and the US EPA has determined that they contribute to air pollution by accelerating the formation of ground-level ozone. It is estimated that significant amount of fumigants will have to be reduced or discontinued to achieve VOC emission reduction targets (Segawa, 2008). The US EPA also has recently announced new and more stringent safety measures for soil fumigants methyl bromide, chloropicrin, dazomet, metam sodium and metam potassium to increase protections for agricultural workers and bystanders - people who live, work, or otherwise spend time near fields that are fumigated (US EPA, 2008). These regulations will significantly increase the restrictions on the use of the regulated fumigants and directly limit the ability to use them for strawberry fruit production.

There are a number of approaches for producing strawberry fruit on a commercial scale without fumigants. Potential approaches include breeding cultivars resistant to soil-borne diseases, long crop rotation cycles and biofumigation using crucifer crops as green manures (Subbarao et al., 2007). The other main alternative approach to producing strawberry fruit commercially without pre-plant soil fumigation is to grow strawberries using the open field raised-bed system constructed from field soil but to add troughs to the beds and fill them with either sterile substrate or soil. The growth media would be separated from the field soil by a barrier film. If proven viable, this method could eliminate the need for the current pre-plant soil fumigation practices, and provide a production system that could be highly adaptable to different substrate types and planting configurations as would be needed for large scale commercial production in California and other areas in the US.

Because of the much reduced rhizosphere of strawberry plant growing in artificial containers or troughs filled with the soilless media, it will require a high frequency of irrigation with water and/or nutrient solutions (Paranjpe et al., 2003). In an impermeable container system, the nutrient solution is re-circulated. However, if nutrient solution is applied in an open system and is not recovered, the excess is discharged and wasted. There will be serious environmental impacts, and growers must manage the system to eliminate the off-field losses or change to closed systems to avoid discharge of fertilizers. A main concern with adopting the trough system for strawberry production in the open field is water and nutrient management to support plant growth and prevent off-field discharges. Most strawberry growers in California currently irrigate once every 2-3 days through surface drip systems on the raised strawberry beds. Because of uncertainties in the permeability of the liner fabrics, we will explore different irrigation frequencies with the new trough systems.
Objectives:

The overall goal of the multi-disciplinary collaborative project is to develop a new raised-bed trough system for managing soil-borne diseases and pathogens in open field production of strawberry fruit. The ultimate purpose is to avoid diseases and other pests without fumigation. However, the development of a complete commercial system will be a long-term process. Funding this proposal provides the strawberry industry an opportunity to evaluate the feasibility of a broad range of substrate and fabric materials for a new fumigant-free production system. Specific objectives are to:

1. Determine optimal trough configurations, aided with modeling, for effective water and nutrient delivery to meet plant needs,
2. Measure and screen water and nutrient retention characteristics of trough substrate and liner fabric materials, and subsurface soils,
3. Provide technical expertise and assistance in soil moisture measurements, irrigation management, and disease assessment for ongoing field trials conducted by the Strawberry Commission.

Methods:

A combination of modeling, laboratory, and field studies (field trials led by the Strawberry Commission) will be used to select and compare the trough configuration, growth substrate and fabric liner materials for water and nutrient retention. Replicated field trials by the Strawberry Commission will be used to test the design, operation, and effectiveness of the new raised-bed trough systems for strawberry production and for preventing root infestation from soil-borne pathogens.

Experimental procedures to achieve specific objectives are:

Obj. 1 We will use laboratory/greenhouse tests and modeling to determine and simulate water and nutrient distribution and movement in the trough and into/from the underlying soils, and root water and nutrient uptake by strawberries. The water and nutrient modeling capabilities have been validated against many field studies. This finite-element model has the flexibility to create different trough system shapes (with a grid generator program). The goal with the computer modeling is to screen for best combinations of trough configuration, trough substrate and fabric materials for maximum efficiency of water and nutrient delivery and minimal losses. Combinations of scenarios will include, but not limited to, the following selections:

- Trough configurations – Option A and B for a 2 row bed system; Option C and D for a 4 row bed system (Fig. 1):
  - Option A consists of two inverted triangular troughs per bed, filled with a sterile substrate medium, planted with one row of strawberry plants each trough or two rows of strawberries per bed, and irrigated and fertigated with two separate lines of drip irrigation tubing/tapes – selected for the Monterey Bay Academy trial by the Strawberry Commission.
  - Option B consists of one half-moon shaped trough per bed, filled with a sterile substrate medium, planted with two rows of strawberry plants per trough or
two rows of strawberries per bed, and irrigated and fertigated with one drip irrigation tubing/tape at the center of each trough.

- Option C consists of two half-moon shaped troughs per bed, filled with a sterile substrate medium, planted with two rows of strawberry plants per trough or four rows of strawberries per bed, and irrigated and fertigated with one drip irrigation tubing/tape at the center of each trough – selected for the Santa Maria trial by the Commission.

- Option D consists of four inverted triangular troughs per bed, filled with a sterile substrate medium, planted with one row of strawberry plants each trough or four rows of strawberries per bed, and irrigated and fertigated with separate lines of drip irrigation tubing/tapes for each row.

Figure 1. Trough configurations
**Obj. 2** Laboratory testing will be needed to determine the water holding and retention properties of trough substrate materials, permeability and water transmission characteristics of the fabrics, and hydraulic properties of underlying soils. These parameters will be used to screen and select the most suitable materials for field tests and in model simulations.

*Substrate materials* in troughs will be tested using the following tentative list of materials: coconut husks or coir, and its mixtures with rice hulls, peat, and perlite. A possible combination is listed below:

- Sterilized native soil from the same field
- Regular coir (100%)
- 2:1 mix of coir and rice hulls
- 2:1 mix of peat and rice hulls
- Mix of peat and perlite
- Almond shells

The information is generally not available and there is no standard methodology for testing these types of artificial media. We will use low pressure systems to derive a water retention function using Tempe Cells or the pressure plate method at low pressure settings. Hydraulic conductivity will also be measured by constructing a high flow apparatus using a constant or falling head approach. Retention with nutrient chemicals will be determined by running breakthrough curves using nitrate and/or Br as tracers.

We anticipate that the effort of testing the sterilized soil will be straightforward as typical soil testing procedures can be applied. A moisture release curve will be made for each soil type using the standard pressure plate methods. Saturated hydraulic conductivity will be measured with a constant head apparatus available at the PIs lab. Particle size and chemical analyses will be conducted using a certified commercial soil testing facility.

*Fabric materials* - water permeability will be the primary interest in selecting the fabric liner materials. Additional information is the strength and durability for field applications, and ability to prevent root penetration. Options for permeability are those fabric liners - landscape cloth used by the Strawberry Commission in their field trials plus additional fabrics for future inclusion in field tests. Following characteristics will be determined:

- Water permeability will be determined using laboratory apparatus has a constant hydraulic head across the cloth materials and the rate of volume change will be recorded to compute for the permeability values of the fabrics.
- Ability to prevent root penetration to subsurface soils will be monitored in pots studies and in field trials. This property is important to physically separate the possible infestation from indigenous pathogens.
- Ability to exclude soil-borne pathogens from the subsurface soil from penetrating to the growth media.
- Interaction with nutrient chemicals will be measured using repeated saturation and desaturation (with the full strength nutrient solution) and each chemical species quantified with an ICP-MS. The PI has direct access to ICP-MS equipment for use in the project.
Subsurface soils. Soils will be tested to represent the major strawberry fruit production districts in California. We will collect soils from the same field site for the Strawberry Commission field trials and they will represent the:

- Watsonville/Salinas Soil
- Santa Maria Soil
- Oxnard/Ventura Soil

The effort of documenting the hydraulic and chemical retention properties of these soils will be in concert with the determination of sterilized soils to be used in the troughs. The assumption is that steam or chemical sterilization of these soils will have no impact on their physical, hydrologic, and chemical properties. The assumption is reasonable because overall these soils contain very low organic content and low microbial populations that would have minimal effect on physical and chemical characteristics of the media. This assumption will be tested or validated by comparing a sterilized and non-sterilized sandy loam soil. If the results were significantly different, then we would have to run separate tests for all the soils that to be used in the troughs after sterilization and those not sterilized.

**Obj. 3** We will provide technical support in soil moisture measurements, irrigation management, and disease assessment for ongoing field trials conducted by the Strawberry Commission.

*Soil moisture measurement.* We will help design, select, and install a TDR system within the troughs and in the subsurface soil below the fabric liners for automated recording of water content during each field experiment. The moisture content measurement will provide important information on the available water in the troughs for strawberry plants. It will also be utilized to supplement the irrigation scheduling using potential ET and a crop coefficient for different growth stages. Because of the drastically reduced rhizosphere for root water uptake, the literature values of strawberry crop coefficient may not be appropriate. However, they will serve as a starting point for making irrigation decisions. Future studies may be needed to focus on developing strawberry crop coefficient for the raise-bed trough systems.

*Irrigation management.* We will help design and provide technical guidance on the operation of a drip irrigation system for the new trough system. We will also assist in the installation of a weather station at the field trial sites for collecting micrometeorological data for computing the real-time potential ET. Drip irrigation rate and frequency to meet 100% strawberry ET requirement will depend on the substrate materials’ water holding capacity or available water for plant uptake, the size of the troughs or total substrate volume per plant, plant evapotranspiration demand which is a function of the growth stage or plant size and atmospheric conditions. A literature crop coefficient for strawberries will be used with potential ET computed using real-time parameters collected from an onsite weather station.

*Disease/pest assessment* will be conducted before and after each field experiment by collecting strawberry plant petiole samples or root pieces, the trough materials, and subsurface soils. Fungal pathogens such as *Verticillium dahliae*, *Phytophthora cactorum*, *Macrophomina phaseolina*, *Colletotrichum acutatum* will be measured.

**Proposed schedule:**
The first year funding was approved late in 2008 and we just started on setting up the experiments to test the new substrate and fabric materials. For the second year, we will be able
to put the project in full operation with laboratory and modeling studies conducted simultaneously. A proposed schedule of activity is:

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<tr>
<th>Task</th>
<th>Target date</th>
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<tr>
<td>Conduct lab testing of substrate and fabric materials</td>
<td>Feb-Aug, 2009</td>
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<tr>
<td>Trough configuration design modeling and system operation</td>
<td>Feb-Jun, 2009</td>
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<tr>
<td>Drip system design, irrigation scheduling, system modifications</td>
<td>March-Nov 2009</td>
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<tr>
<td>Field monitoring and measurement of soil moisture and nutrient</td>
<td>March – Nov 2009</td>
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<tr>
<td>Disease sampling and lab determination</td>
<td>March 2009 – Jan 2010</td>
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<td>Presentation at MBAO</td>
<td>Nov 2009</td>
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<td>Report submission</td>
<td>Dec 2009</td>
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**Literature review:**
Commercial production of strawberry fruit in soilless media has been used extensively in Europe using peat moss, coconut coir, perlite, rockwool, or pine bark (Lieten, 2005) or a mixture of these materials (Takeda, 1999) in different types of containers or troughs (Dijkstra et al., 1993). The high cost and high maintenance requirements of these production systems have limited their application to relatively small areas in protected environments such as greenhouses or high tunnels (Kempler, 2002). In Florida, growing strawberries in protective structures can also provide protection against low temperatures in the winter production season, ensuring the growers consistent fruit yield and quality. No open field production of strawberry fruit has been practiced on a commercial scale using artificial containers or troughs filled with the soilless substrate media.

**References:**