Site-Specific Application of Fumigants to Minimze Input, Reduce Cost, and Protect the Environment

Project No.: **07-ENVIR8-Upadhyaya**

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Interpretive Summary:

The goal of this research was to use recent advances in the global positioning system and computer technology to apply just the right amount of fumigant where it is most needed (i.e., in the neighborhood of each tree planting site or tree-planting-site-specific application) to decrease the incidence of replant disease, and achieve the environmental and economical benefits of reducing the application of these chemicals. During the 2006 - 2007 growing season, we retrofitted a chemical applicator with a high-performance global positioning system receiver (accuracy in the range of 10 to 20 cm), an embedded controller to read GPS data and control a solenoid valve to implement

tree-planting-site-specific fumigant application. Although the system worked well, the results of accuracy tests indicated that the RMS error in position location was 33.5 cm, which was more than desirable. To improve the position location accuracy, a new system was developed during the 2007 - 2008 growing season. In this system, the embedded controller which was slow to perform all the necessary computations in real-time was replaced with a higher speed controller that used a Pulse Width Module (PWM) and solenoid actuated nozzles to provide precision rate on demand. Extensive testing indicated that the new system had a RMS error of less than 15 cm. The system was field tested in three almond orchards in California during fall 2007. The system performed well in all three locations. Based on the success of the 2007 system we developed a user friendly system for the 2008 growing system. This system integrated the gridding and navigation aspects into one single step using a touch screen approach, thus making it an easy to use system for the operators.

Objectives:

The goal of this research was to use recent advances in the global positioning system and computer technology to limiting the soil fumigant application to where it is most needed (i.e., in the neighborhood of each tree planting site) and achieve the environmental and economical benefits of minimizing the application of these chemicals. While the usual rates of fumigant are applied, they are only applied to some 11% of the total acreage.

Development of the Global Positioning Systems (GPS) has made high accuracy location determination very convenient anywhere on the surface of the earth. GPS receivers with different accuracies are available depending on the intended applications. A very recent development in GPS technology is the availability of high performance (HP) receivers that are capable of delivering 10 to 20 cm accuracy using a dual frequency, satellite based, differential correction signal. These receivers cost about four thousand dollars and are particularly suited for agricultural chemical applications such as soil fumigation. During the 2006-07 growing season, we retrofitted a conventional subsoil shank fumigation system supplied by TriCal Inc.[1], Hollister, California, USA with a tree-planting-site fumigant application system shown in Figure 1.

[1] Mention of trade names is not an endorsement of the product by the authors or the University of California Davis.

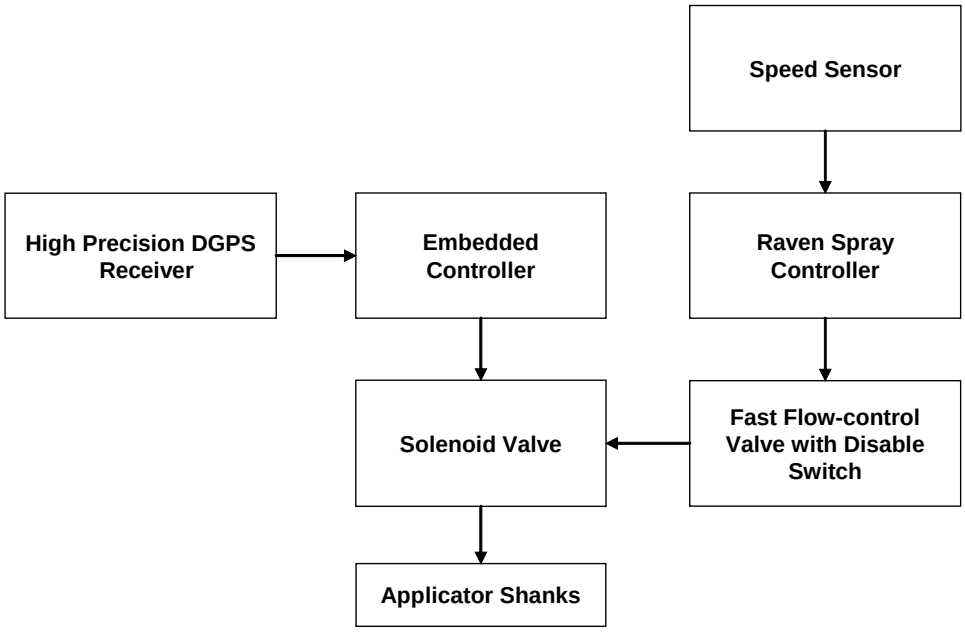

Figure 1. Schematic of the modified tree-planting-site fumigant application system

Extensive tests indicated that the RMS error due to this system was 33.5 cm (13.1in). This means that to ensure a 1.5 m (5ft) long zone receives fumigation 95% of the time, a 2.8 m (9.3 ft) long zone needs to be treated. For the HP GPS system used, we expected an RMS accuracy in the range of 10 to 20 cm. This design did not fully realize the accuracy level expected from the HPGPS unit. To address this limitation, an improved system was developed and tested during the 2007 season.

Figure 2a shows the schematic diagram of the newly developed system. The system consists of a precision fumigant controller (PFC) which is connected to a HPGPS unit, an inclination sensor, a Pulse Width Modulation (PWM) unit and a Raven Flow controller[1]. The PWM unit controlled solenoid actuated nozzles that are located on the applicator shanks to apply desired amounts of fumigant. Figure 2b shows the TriCal fumigant applicator retrofitted with planting-site-specific fumigant application system. A tree gridding program that produced the coordinates of the tree planting sites based on the coordinates of the corner trees, row spacing, and tree spacing along the row was developed. Moreover, the gridding program allowed the trees to be planted in a rectangular or diagonal pattern. The tree gridding data are uploaded to the PFC so that tre planting-site-specific fumigantion could be achieved. Extensive road and field testing indicated that the new system had a RMS error of less than 15 cm or 6 in. (Udompetaikul et al., 2008). The system was field tested in three almond orchards in California during the fall of 2007. The system performed well in all three locations. The specific objectives of the 2008 research plan were:

(1) Enhancement of both hardware and software so that tree planting site-specific fumigant application is easy to use for the applicator operator, and
(2) Test the improved system for accuracy and conduct fumigant application tests in orchards.

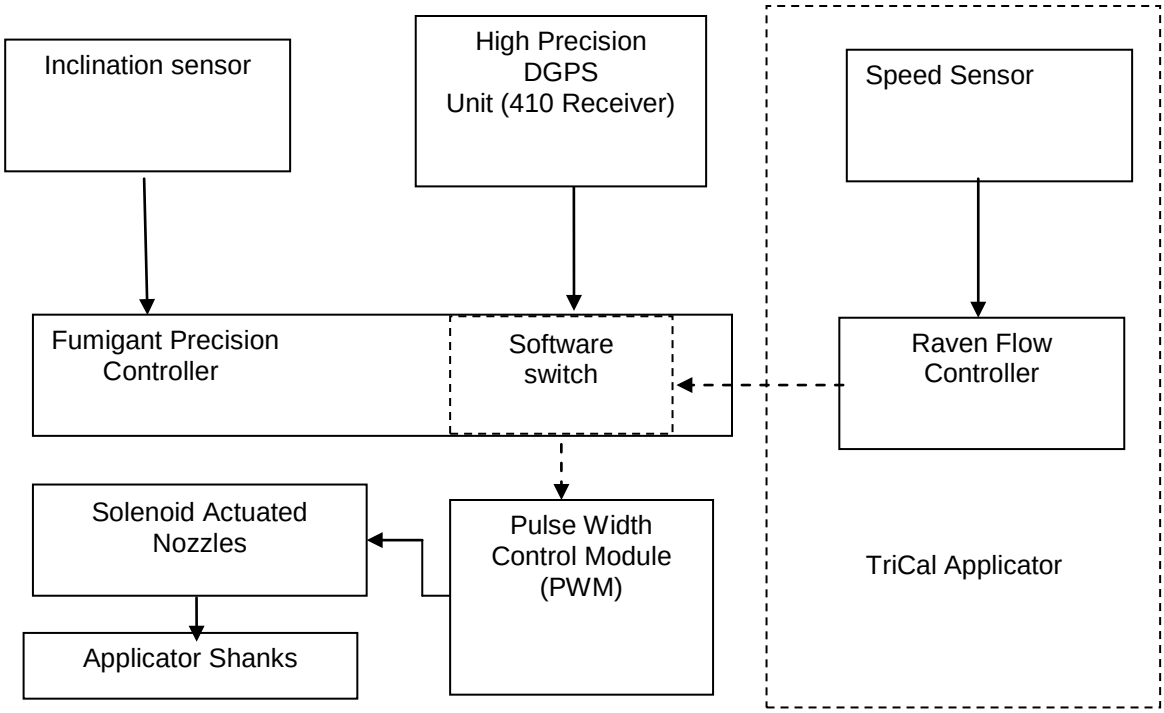

Figure 2a. Schematic of the fine-tuned site-specific fumigant application system

Figure 2b. TriCal Shank type fumigant applicator retrofitted with a planting-site specific fumigant applicationsystem.

Materials and Methods:

Figure 3 shows a schematic diagram of the improved system developed during the 2008 season. It uses a touch screen technique to input information to the PFC. The operator can select either a gridding mode or a navigation mode. In the gridding mode the system allows the operator to move to the four corners of orchard and mark them using the HPGPS unit. The operator simply aligns the center shank fumigant discharge point with the corner points to mark them since the HPGPS antenna is directly above the center shank fumigant discharge point. The system also allows any offset, if present, to be entered. Once the four corners are marked, PFC displays the boundary of the orchard and allows the operator to select the row direction and the orchard edge along which all rows start. Then it allows the operator to select/adjust the tree spacing (TS) along the row and row spacing (RS). Moreover, it provides the option to plant the trees in a retangular or diagonal fashion (D) and the fumigant application zone radius (R). Once PFC obtains these four inputs interactively (TS, RS, D, and R) it grids the whole orchard. If the displayed grid is not satisfactory, it can easily be changed using touch screen prompts. It allows for fine tuning tree spacing and row spacing so that desired palnting pattern is generated. Upon generation of the desired planting pattern, the PFC is ready to navigate to the individual tree planting sites to perform tree planting-site-specific fumigant application.

The navigation option is used to perform the tree spot fumigantion treatment. This part of the hardware and software are essentially similar to the one used during the 2007 season. This year's system uses LEDs (essentially a lightbar) to assist the operator in navigating along the rows. The system also records on the flash memory the fumigant application rate and the GPS coordinates at which that rate is applied to provide data necessary to create an as applied map.

Tests for Positional Accuracy:

Positional accuracy tests were conducted near the Western Center for Agricultural Equipment (WCAE) on the UC Davis campus using 12 marked points laid in a rectangular pattern as shown in figure 4. The application zone length was 1.8 m (72 in.) The applicator was operated at 3.2, 5.6, and 8 km/h (2, 3.5, and 5 mph) to determine the appropriate look ahead value (LAV). This test was repeated after incorporating the LAV to determine the positional accuracy of application. It should be noted that the system allows for the LAV to be changed based on test results.

Orchard Tests:

The system will be used to perfom tree planting-site specific-fumigantion treatment in two orchards in Parlier, CA this fall.

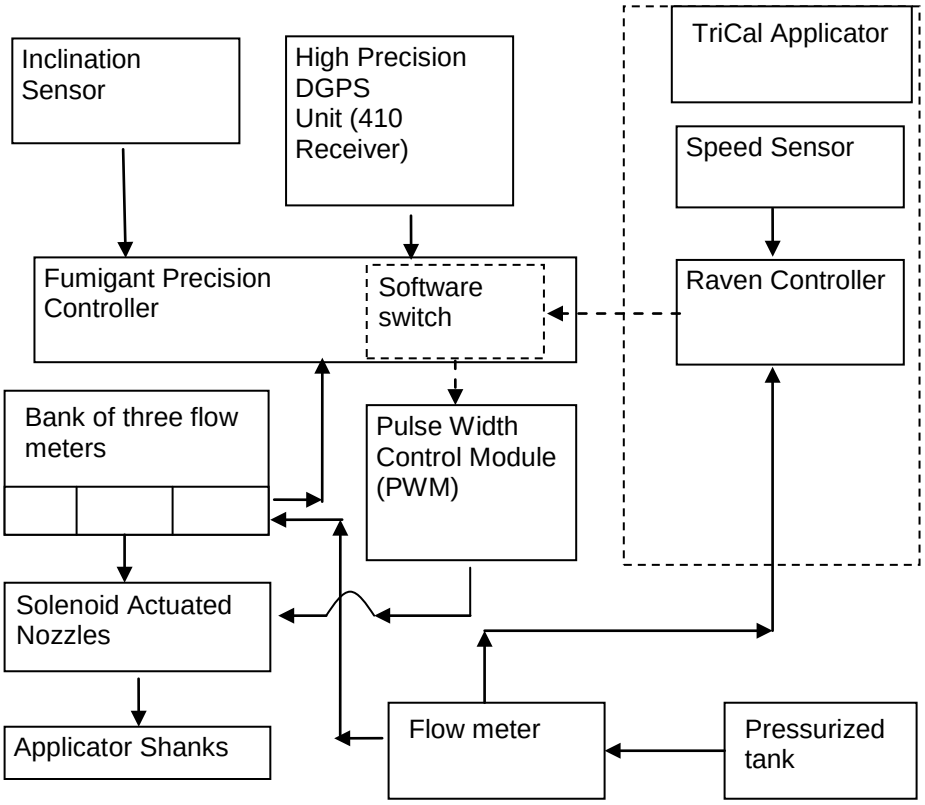

Figure 3. Schematic diagram of the proposed system

Results and Discussion:

Accuracy Test Results:

The first series of tests conducted to determine the appropriate LAV for the system revealed that the LAV for the new system was 245 ms. When this LAV was entered into the system and the system was tested again the average length of the application zone was found to be 1.7 m (67 in.) with a standard deviation of 0.1 m (4.2 in.). The coefficient of variation was 6.3%. This level of accuracy was within the range of accuracy expected with the HPGPS system. Therefore the system was considered ready for tree planting-site specific fumigant application.

Orchard Tests:

As mentioned in the materials and methods section the orchard fumigation trials will be conducted early in November in Parlier, CA.

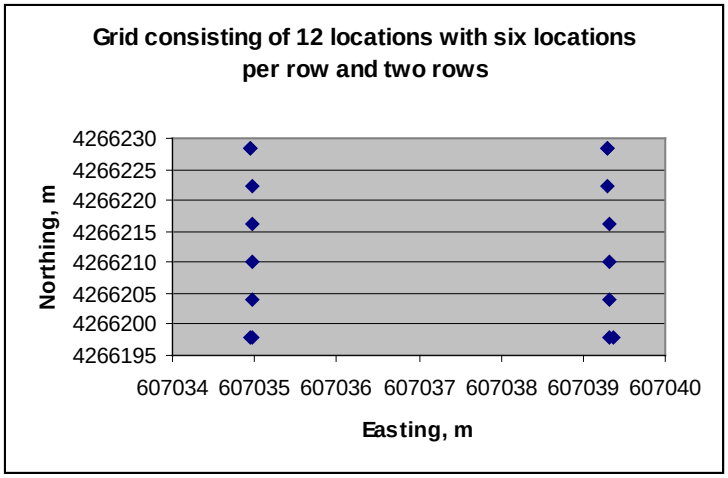

Figure 4. Accuracy test grid created using the 2008 system to check the accuracy of the system. Grid points are laid out in a rectangular pattern with a spacing of 6.1 m (20 ft) between the rows and 4.6 m (15 ft) between the rows.

Conclusions:

Based on this study in which a shank-type fumigant applicator was used to develop a tree-planting-site-specific fumigant system, we reached the following conclusions.

1. The HPGPS based system worked satisfactorily during the position accuracy tests conducted near WCAE on the UC Davis campus.
2. The look-ahead-values were found to be 245 ms on an average.
3. Field test results indicated that the RMS error in locating the position was less than 11 cm (4.2 in.) and the coefficient of variation in application zone length was 6.3%.

Recent Publications:

Upadhyaya, S. K., V. Udompetaikul, M. S. Shafii, and G. T. Browne. 2008. Design, Development and Evaluation of a Tree Planting-Site-Specific Fumigant Applicator. Proceedings of the First International Symposium on Precision Agriculture for Fruits and Vegetables, January 7-9, Orlando, FL.

Udompetaikul, V, M. S. Shafii, S. K. Upadhyaya, G. Browne, and D. Neves. 2008. Planting Site-Specific Application of Fumigant in Orchards. ASABE Paper No. 083775. ASABE, St. Joseph, MI 49085

Upadhyaya, S.K., V. Udompetaikul, M. S. Shafii, and G. T. Browne. 2008. A Tree Planting Site-Specific Fumigant Applicator for Orchard Crops. Proceedings of the 9th Annual International Conference on Precision Agriculture. July 20-23, Denver, CO.