

In-Row Weeding in Vegetables with a Machine Vision-Guided Cultivator

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Summary. We are evaluating a robotic cultivator to determine if it can be used to increase the efficiency of vegetable production by removing weeds from between lettuce and tomato plants in the row. Additionally, we will determine if this machine can be used to thin direct seeded lettuce and tomato to desired stands. Hand weeding is a significant expense for vegetable growers because vegetable herbicides do not adequately control weeds. Currently the only way to remove weeds from within the crop row is by hoeing, hand weeding and selective herbicides. The Tillet rotating cultivator (a robotic cultivator), being sold commercially in England, is capable of removing weeds from the crop row. Direct-seeded crops are generally planted at high stands and then thinned by hand to desired stands at \$80 to \$150/acre. A mechanical crop thinner could potentially reduce production costs for direct seeded crops if handweeding can be reduced or eliminated. The purpose of this project is to test the rotating cultivator in typical California vegetable production systems and determine if it is effective at crop thinning, removing weeds and reducing time of hand thinning and weeding in lettuce and tomato. The rotating cultivator does appear to be capable of thinning lettuce to desired stands if the lettuce is seeded with at least 3 inch spacing between seedlings in the row. If the seedlings are closer than 3 inches then the cultivator is more error prone, so precision seeding is necessary for use with this cultivator. Our tests of the rotating cultivator and subsequent timing of handweeding indicate that less labor is required to hand weed lettuce or tomato cultivated with the rotating cultivator than a standard cultivator.

Introduction. Weeds are among the most common pests of vegetable crops, and present a constant obstacle to profitable vegetable production. Herbicides available to vegetable growers are few in number and those few do not control all weeds. Therefore, vegetable crops almost always require hand weeding and cultivation to maintain cost-effective weed control. Labor costs are increasing, and labor shortages have been reported. Methods to hold down hand weeding costs are necessary if growers are to remain profitable. Stakeholders have noted that weed management in tomato is a major limitation for profitable production. Additionally, stakeholders have stated that the development of “effective economical management techniques for weeds” is a “high” research priority for lettuce. Uncontrolled weeds in vegetables result in lower yields, reduced quality, and decreased harvest efficiency, particularly in hand-harvested crops such as lettuce. Lettuce and tomato are very susceptible to weed competition. Given the scarcity of labor and new herbicides for vegetables, it seems prudent to evaluate robotic cultivators for in row weeding in lettuce and tomato.

Materials and methods. Field studies were conducted in lettuce and tomato to evaluate the potential to improve the efficiency of labor utilization by increasing the mechanical removal of weeds. Lettuce trials were established by direct seeding on 40-inch raised beds with 2 seed lines per bed. Tomato trials were established on 60 to 80 inch beds by transplanting. The herbicide program for lettuce was pronamide at 1.2 lb ai/A applied post plant Preemergence. The herbicide program for tomato was rimsulfuron applied immediately after seeding or transplanting at 0.5 oz

ai/A followed by trifluralin at layby at 0.75 lb ai/A. The standard cultivator was a combination of cultivator knives and sweeps that cultivate the entire bed with the exception of 3 inches centered on the crop seedline. The rotating cultivator was also used in combination with the sweeps and knives, but the rotating cultivator also weeded in the seedline.

Approximately 21 to 28 days after seeding, lettuce and tomato were thinned with the rotating cultivator set to cultivate the entire bed top and row middles. The trial design was a split plot arranged in a randomized complete block design with four replicates. Cultivator design, rotating cultivator/standard cultivator, were the main plot, the split plots were herbicide (with or without) and the split-split plot was hand thinning and weeding. Evaluations included stand counts to evaluate the impact of the close cultivation on the lettuce or tomato stand, visual vigor estimates, weed counts prior to and following cultivation, as well as timing of lettuce or tomato thinning and timing of hand weeding operations in lettuce and tomato to support economic analysis. Lettuce yield evaluations were based on fresh weights from 25 ft of plot. Tomato fruit were harvested at commercial maturity from 25 ft of plot. Six trials were conducted in 2009. The data were subjected to analysis of variance and LSD's were used for mean separation.

Results. On June 17, 2009 a commercial direct-seeded lettuce planting at a commercial farm near Gonzales, CA was thinned and weeded with the rotating cultivator and standard cultivator. After thinning with the rotating cultivator and the standard cultivator, the entire trial was hand thinned. Plots cultivated with the grower's standard cultivator required 11.6 hours to thin, while plots thinned with the rotating cultivator required 4.2 hours per acre to hand thin a 64% reduction in labor input required.

A direct-seeded lettuce planting on the Spence research station near Salinas, CA was thinned with the rotating cultivator on June 18, 2009, hand thinned on June 22, 2009 and hand weeded on July 1, 2009. Standard cultivation was also conducted on June 18, 2009. The total hand thinning and weeding in the rotating cultivator treatment was 21.6 hours per acre compared to 31.2 hours per acre in the standard cultivation plots for a 31% reduction in hand weeding effort in the rotating cultivator vs. standard cultivator treatments.

A transplanted tomato evaluation on the Hartnell research farm near Salinas, CA was cultivated with a standard cultivator on July 8, 2009 and the rotating cultivator on July 9, 2009 and hand weeded on July 14, 2009. The handweeding times in the rotating cultivator treatments were 5.6 hours/A and in the standard cultivator were 7.1 hours/A. The rotating cultivator removed most of the weeds around the tomato plants resulting in a 21% reduction in handweeding time compared to the standard cultivator.