SCIENTIFIC NOTE

Split-Application of *Bacillus thuringiensis israelensis* to Control Asian Tiger Mosquito, *Aedes albopictus* (Skuse) (Diptera:Culicidae) without Reducing Lettuce Head Weight in Non-Circulating Hydroponics

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Abstract. Vectobac G (*Bacillus thuringiensis israelensis*) application at 1.08 and 0.54g/m^2 to subirrigated pot and suspended forestry tube methods of non-circulating hydroponics in an unreplicated experiment greatly reduced numbers of Asian tiger mosquito, *Aedes albopictus* (Skuse) (Diptera: Culicidae), larvae and pupae compared to non-treated controls. Both Vectobac G rates, however, reduced lettuce head weight and root growth compared to the control. When the 0.54/m^2 rate was applied as a split-application (0.27g/m^2 applied 2 weeks apart), *A. albopictus* larvae and pupae were still controlled throughout the lettuce cropping cycle and lettuce head weight was not significantly affected. Therefore, the split-application of Vectobac G may be an effective strategy to control mosquitos breeding in commercialized non-circulating hydroponic lettuce operations in Hawaii.

The recent development of non-circulating hydroponics (Kratky 1990, 1993) has given rise to several commercial operations utilizing this method of crop culture in Hawaii. A problem that has become apparent with its use is the breeding of mosquitoes, *Aedes albopictus* (Skuse) (Diptera: Culicidae) in the stagnant water (Furutani & Arita-Tsutsumi in review) of the hydroponic tanks. Since all of the crops produced by hydroponic culture in Hawaii are primarily marketed as a pesticide-free, conventional pesticides are not a viable option for the farmers.

In a companion paper, Furutani and Arita-Tsutsumi (2001) tested methoprene and *Bacillus thuringiensis israelensis* (Bti) for control of *A. albopictus*. Methoprene, a juvenile hormone, effectively controlled *A. albopictus* larvae and pupae, but severely reduced head weight and root growth of semi-heading lettuce. Bti controlled *A. albopictus* larvae and pupae in non-circulating hydroponic tanks at the 1.08g/m^2 concentration, but the formulation greatly affected the head weight of several varieties of semi-heading lettuce. Of the formulations tested, an organic vermiculite carrier impregnated with Bti (Vectobac G, Abbott Laboratory, Chemical and Agricultural Products Division, North Chicago, IL) had the least tendency to reduce lettuce head weight and root growth, however, even treatment at 0.5 times the recommended rate (0.54g/m^2) reduced head weight and root growth.

The purpose of the study was to observe the effect of a split-application of Bti on mosquito control and on head weight and root growth of lettuce when cultivated with 2 non-circulating hydroponic systems currently being used in Hawaii.

Materials and Methods

Hydroponic tank construction. ***Subirrigated pot method.*** Four hydroponic tanks each measuring 2.44 m long, 1.22 m wide by 19 cm deep were constructed with 1.9 cm thick exterior plywood (2.44 x 1.22 m). The tanks sides were constructed with 5.1 x 10.2 cm lumber. The inner surface of the tank was lined with 3 layers of 6 ml-thick black polyethylene sheeting. A black polypropylene woven cloth (weed cloth) was drawn tightly of the top of the tank that served as a top cover. A 0.75 m section of the top cover was left uncovered to allow mosquitoes free access to the water within the tanks. Thirty equally spaced holes were cut into the polypropylene top-cover to allow the passage of standard 10.5 cm square plastic pots to sit squarely on the bottom of the tank.

Suspended forestry tube method. Two hydroponic tanks were constructed as above with a tank depth of 20.3 cm. Each tank was then partitioned with each half measuring 1.22 X 1.22m. The bottoms of the tanks were lined as described above. A plywood sheet (1.25 cm thick) was used for the tank cover that also served as the support for the forestry tubes (3.8 cm in diameter x 20.3 cm long plastic tubes in which the lettuce seedlings were planted). Twenty-five equally spaced holes per 1.22 x 1.22 m compartment (3.8 cm) were drilled through the plywood top-cover to support the forestry tubes. Five holes per compartment were left open to allow mosquitoes excess into the tanks. The upper surface of the plywood top-cover was painted white to reduce surface temperature.

Seedlings and nutrient solution. 'Manoa' lettuce, *Lactuca sativa* L., seedlings were prepared by first sowing seeds 0.25 cm deep into seedling trays filled with a standard potting mix (Pro-mix BX, Ontario, Canada). The seedlings were grown under a fiberglass-covered greenhouse for 10 days before transplanting. The lettuce seedlings were transplanted into the subirrigated pots and the suspended forestry tubes containing a 1: 1: 1 mixture of peat : vermiculite (no. 2 grade) : horticultural perlite (medium grade).

The nutrient solution was prepared as described by Kratky 1996. The nutrient solution was 4.0 cm deep for subirrigated pots and 10.0 cm deep for suspended forestry tubes. The following rate of nutrient solution was added to each subirrigated pot tank: 72g of 4-18-38 hydroponic mix (Chemgro, Hydro-gardens, Inc., Colorado Springs, CO 80932) 72 g $CaNO_3$, 15 g KNO_3, and 43 g $MgSO_4$. One half of the above mentioned amount was added to each compartment of the suspended forestry tube method. No additional fertilizers were added to the tanks. Electrical conductivity (1.5 ± 0.5 milli-siemens, mS) and pH (6.5 ± 1.0 pH) of the nutrient solution were monitored weekly and maintained for optimal growth.

Mosquito larvae and pupae were monitored weekly in subirrigated pots by visually counting live individuals within the open area ($0.75\ m^2$) of the tank. Populations for the suspended forestry tubes were taken by counting the live individuals in each compartment at harvest. Weekly population counts could not be taken since the tank top-cover, which suspends the forestry tubes, could not be raised during the experiment without injury to the lettuce plants.

The lettuce seeds were sown 12 May 1998 and transplanted 19 May into the subirrigated pots. The plants grown in the subirrigated pots were harvested 19 June and the plants grown in suspended forestry tubes were harvested 25 June. Mosquito larval and pupal counts, lettuce head weights (g) at harvest, and root growth was rated on a scale of 0 to 4 (0 = no visible roots protruding from the pots or tubes; 4 = prolific root growth visible from the pots or tubes).

Bti treatments. Vectobac G was applied at 1.08 g/m^2, 0.54 g/m^2, 0.54g/m^2 split-application (2 applications of 0.27 g/m^2 applied 2 weeks apart), and 0g/m^2 (non-treated control). Vectobac G was applied to the nutrient solution in both the subirrigated pots and the suspended forestry tubes one week after planting, except for the split-application treatment which received a second application 3 weeks after planting.

The experimental tanks were built to duplicate tanks that are currently used in commercial hydroponic lettuce farms in Hawaii. Due to the size of these tanks and the limited greenhouse space available for this study, treatments were not replicated. However, the experimental hydroponic tanks should closely reflect plant growth and mosquito control in commercial operations.

Table 1. Effect of Vectobac G application rate on mean ± SEM head weight and root rating of 'Manoa' lettuce grown in subirrigated pot and suspended forestry tube method.

	Subirrigated pots[x]		Suspended forestry tubes[y]	
Vectobac G (g/m^2)	Head wt. (g)	Root rating[Z]	Head wt. (g)	Root rating
0.00	86.0±2.20	1.9±0.14	156.2±8.98	3.5±0.22
1.08	47.7±1.62	0.7±0.11	140.2±7.79	2.0±0.19
0.54	77.0±2.40	1.1±0.14	146.0±8.69	2.5±0.20
0.54 (split)	90.9±2.00	1.3±0.12	174.6±6.04	3.5±0.21

[x] N=30 plants (1 plant per pot)
[y] N=20 plants (1 plant/tube)
[Z] Root rating (0 = no visible root mass; 4 = very prolific root mass)

Results and Discussion

'Manoa' lettuce plants in subirrigated pots that were grown in nutrient solution treated with Vectobac G at $1.08 g/m^2$ and $0.54 g/m^2$ had significantly reduced head weight compared to the non-treated control and the $0.54 g/m^2$ split-application treatment (Table 1). Plants grown with suspended forestry tube method had similar head weight results.

Root mass rating for the control in subirrigated pots was higher than the 0.54 and $0.54 g/m^2$ split-application which was, in turn, higher than the $1.08 g/m^2$ application rate. In the forestry tubes, the control and the $0.54 g/m^2$ split-application rates had more root growth compared to the 1.08 or the $0.54 g/m^2$ application rates (Table 1). A plausible explanation for the reduced root growth difference is the volume of water used in each system. The suspended forestry tube method requires over 2.5 times the water volume used in the subirrigated pot method.

There were no larvae or pupae for all Vectobac G treatments during the cropping cycle (with the exception of 1 $larva/m^2$ for the $0.54 g/m^2$ treatment 30 days after planting for the subirrigated pot method) (Fig. 1). The control had 15 to 20 $individuals/m^2$ after 20 days. For the suspended forestry tube method, all Vectobac G treated tanks had less than 5 larvae and $pupae/m^2$ at harvest (38 days after planting). In comparison, the control had over 100 larvae and $pupae/m^2$ at harvest.

In conclusion, a one-half recommended rate of $0.54 g/m^2$ applied as a split-application, the first applied 1 week after transplanting; and a second application during the 3 week after transplanting, effectively reduced numbers of mosquito larvae and pupae without reducing head weight of 'Manoa' lettuce. While lettuce treated with the split-application of Bti did not have decreased root growth compared to the control when grown under the forestry tube method, root growth was significantly reduced when grown with subirrigated pots. Vectobac G, at this time is not labeled for the use described above.

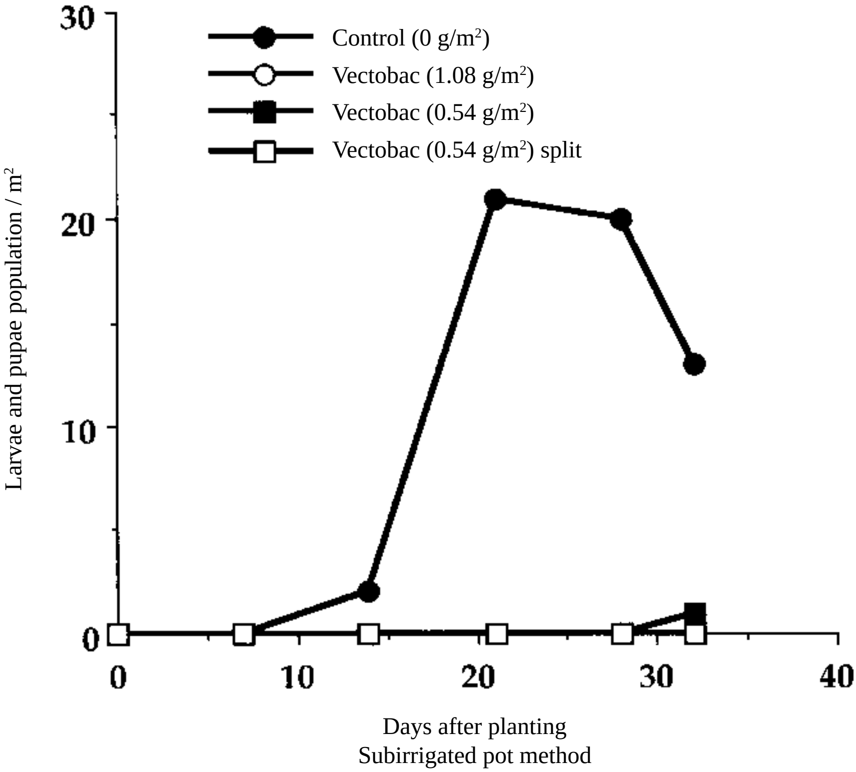

Figure 1. Effect of Vectobac G application rate on controlling mosquito larvae and pupae in subirrigated pots.

Acknowledgments

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