DESIGN AND PERFORMANCE OF METERING DEVICES FOR DISTRIBUTION OF PREDACEOUS MITES

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Abstract

A ram-venturi metering and distribution system for predaceous mites was further evaluated under both laboratory and field conditions. It was found to be unacceptable because of unexplained inconsistencies of mite survival and distribution. Both auger and belt metering devices were evaluated for mite survivability and show good potential for metering mites. The belt system is more adaptable to low metering rates and requires less power to operate. A mite metering system that requires tumbling to maintain uniformity in a mite-carrier material is unacceptable because of high mite mortality, especially after 8 minutes of tumbling.

Introduction

Spider mites are major pests for a number of crops including cotton. Although natural enemies do exist and are often exploited successfully in tree and vine crops, control of these pests in field crops continues to be dependent on synthetic organic chemicals. In critically infested areas, spider mites are now the target of three or more applications of acaricidal compounds each year.

Alternatives to acaricidal control of spider mites include 1) preservation of the established biological control organisms and 2) release of predaceous mites. Inoculative releases of certain species have proven successful in orchards (Hoy 1982) and vineyards (Flaherty & Huffaker 1970). Predaceous mites are used commercially for spider mite control on strawberry. Less effort has been made to utilize predaceous mites in annual field crops. Releases have been made in corn in Texas (Picket and Gilstrap, 1986; Picket et.al., 1987) and exploratory releases have made into corn and cotton in California (Tijeriana-C. 1991).

The potential for released predaceous mites in field crops such as cotton and corn has been established in the doctoral dissertation research at Shafter by Arturo Tijerina (Tijerina-C. 1991).. *M. occidentalis* was released at predator:prey ratios of 1:5, 1:10, 1:20 and 1:40 with significant reductions in spider mite numbers at the higher release densities. The methodology for release was suitable only for small research plots.

There is little literature of mechanized release of predaceous mites in field crops. Commonly, the predaceous mites are shipped in 500 mL plastic bottles and applied at rates of approximately 2,000 to 20,000 mites/L of a carrier such as vermiculite or corn grit with an variable number of food mites. Application rates of *P. persimilis* in strawberry culture generally range from 25,000 to 75,000 mites /ha in 6 to 18 L/ha carrier. (Giles, 1995). When distributed by walking , the common technique is to shake a discrete amount of the mixture onto the foliage at the rate of one to two portions per step with the mixture depending upon the definition of a portion and the repetition rate. Possibly the first mechanical method simulating the manual method is described in patent number 4,966,329 (Show, 1990). It describes a rotating applicator powered by a ground wheel that drops a measured amount per rotation but since both the meter and tractor are moving the result is better described as a dribble over a distance represented by about 50% of meter rotation. A team at Shafter, California (Carter, 1992) described a metering and delivery system using a ram-venturi and high velocity plume for metering and distributing predaceous mites in corn grits. Giles and associates conducted definitive studies showing that predaceous mites were highly mobile within the mixture held for application and mortality increased with time of tumbling whether used to maintain uniform concentration or provide metering (Giles, 1995). He concluded that the a practical method of maintaining a uniform mixture was to immobilize the mites by keeping the mixture at a temperature of 2° C. He describes a plate type meter enclosed in a cool chamber. Using this technology, Warren Sargent president of Ag Attack, Visalia, CA. designed and manufactured a vertical chest, cooled with gel-ice, and with a plate meter.

The research reported here, was prompted by field experience with the existing mechanized metering systems. 1) Unpublished results with the ram-venturi system were not reproducible year to year. One year the efficacy of mite control was high, with the predaceous mites over-running the checks and surrounding fields. In another year few predaceous mites could be recovered. 2) Temperatures significantly below ambient were difficult to maintain in the field with gel-ice therefore the application rates were variable due to upward migration of the predaceous mites. 3) The amount of diluent material required for these methods introduced two problems. The first was the mechanical problem of uniformly mixing the delivered predaceous mites into a much larger volume in the field without excessive tumbling. The second was the necessity of replenishing the distributor frequently contributing to problem 2 and requiring a team of three or more assistants in the field.

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Methods & Materials

Blower - Laboratory Tests

The ram-venturi system (Carter, 1992) was further evaluated because of inconsistencies of previous results. Two metering devices were used for four large scale laboratory tests. The originally described 3-slot vertical tube was used for the first two tests. A horizontal single slot design was used for the latter two tests.

For the first test, 1000 predaceous mites were mixed with 20/40 corn cob grits for a 1 L sample. Control samples (50 mL) were taken prior to testing. The remaining material was blown onto a table area 8 ft wide x 30 ft long that was lined with paper. The captured material was placed into a container and eight 50 mL sub-samples were taken for each of the two runs. Live counts of the predaceous mites were made immediately after testing.

For the second test, a 34 ft x 60 ft area on 2 ft x 5 ft grids was set up in which 181 cups (4 1/4 in diameter) were placed in a grid to catch the dispersed mites and corn grit carrier. Ten thousand mites were mixed with 20/40 corn cob grits for a total of 2 L of material dispersed. Immediately after the test, the cups were capped and placed under refrigeration for subsequent counting of both live and dead mites.

The third test was similar to the second , except two more rows were added to increase the length to 70 ft and the sample size to 209. A single slot metering device was designed for this test in an attempt to confine the velocity profile to the center of the discharge tube. Previous tests with the 3-slot tube metering device showed evidence of mite residue disseminated on the sides of the discharge tube.

The fourth test was similar to the third, except the mites were mixed with vermiculite as a carrier material. The flow characteristics of vermiculite are slower than corn grits so only 500 mL was dispersed. Sticky paper (3 3/4 in x 6 in stapled to 4 1/4 in x 7 in cardboard) was placed in each grid instead of the cups to capture the dispersed mites and carrier. After testing, the sticky paper boards were placed in boxes for counting of live predaceous mites. A mite was considered live if its body was completely intact. No attempt was made to count dead mites on the sticky paper because of the difficulty in distinguishing between food and predator mite body parts.

Mite survivability was determined for all tests, except test 4 which used sticky paper, by counting and removing the predaceous mites that migrated out of the carrier material onto the sides or rim of the sample beakers. Counting was continued until live mites no longer emerged from the carrier.

Blower - Field Tests

In 1995 and 1996, identical tests with the blower and 3-slot metering device were set up in the same location in a cotton field to determine survival and distribution of predaceous mites. Each plot, replicated four times, consisted of a semicircle of 30 ft radius, centered on the edge of the field. Five thousand predaceous mites combined with 2 L of corn grit carrier were distributed at each plot. For sampling, a transit was set up at the edge of the field at the center of the treated area. Samples were made at 0 (1 to 2 ft into the field), 45, 90, 135, and 180 degrees of arc and at a radii of 10, 20, and 30 ft from the center of the plot. At each sample location (within a 6 ft radius of the location), one sample of 10 leaves from the upper third of plants and one sample of 10 leaves from the middle third of plants for a total of 32 samples (320 leaves) per plot were taken. The leaf samples were processed in a mite washer and the prey and predatory mites counted.

Other Metering Devices & Tests

Two important considerations previously mentioned for a mite distribution system are the need to keep the mites cool (2° C) and uniformly mixed within the carrier material. One solution is to reduce the amount of carrier material that contains the mites which infers a greater need for an accurate metering device. The goal was to distribute 500 mL of mite-carrier material per acre. To achieve this accuracy, meter flow rate and tractor ground speed need to be synchronized. For the tests reported, because of their brevity, no attempt was made to keep the mite-carrier material cold during testing; however it was kept cool just prior to testing. Two precision type metering devices are described.

Auger

An auger metering device was designed and constructed using a 1 in diameter ships-type auger. An aluminum housing 5 in long contained the auger and metered the mite-carrier material. An important design consideration for augers is to minimize the distance between the inlet and outlet ports. Another consideration is rotational speed to minimize tumbling and subsequent injury. A slot size of 3/4 in provided the 500 mL /acre delivery with an auger rotation of 5 RPM. This is the rotational speed required for proper distribution rate at 6 MPH travel speed. The auger was driven by a stepping motor which was controlled by a signal generator.

To evaluate survivability , 1000 predaceous mites were mixed with 450 mL of corn grit carrier. Three control samples (30 mL each) were taken at the beginning, middle, and end of testing. Approximately 175 mL of material was ran through the auger. Five replications of 30 mL samples were obtained for evaluation. The samples were placed in 100 mL beakers and the number of live predaceous mites counted.

Belt

A belt metering system with a variable gate was designed for comparison to the auger system. A 4 mil polyethylene belt 2 in wide x 4 in long was mounted into an aluminum frame. A metering box with a 5/16 in x 3/4 in gate placed on top of the belt frame metered the mites and carrier material onto the belt one inch from the discharge end. The gate size was determined by trial and error to distribute 500 mL of mite-carrier material per acre. A stepping motor rotated the belt at 5 RPM for a belt surface speed of 0.65 ft/min.

Survivability was determined similarly to the auger. Two control samples of 20 mL each were made at the beginning and end of each of the two runs. Approximately 175 mL of mite-carrier material was metered onto the belt for each run. Five 20 mL samples were made for each run and evaluated as described earlier.

Tumbling Test

A tumbling test was devised to determine the survivability of mites with respect to time when tumbled at a uniform rate. As was mentioned previously, when larger ratios of carrier material to mites are used some means of mixing is required unless proper temperature can be maintained. Both corn grits and vermiculite were evaluated as carrier materials. For each carrier material 1000 mites were mixed to obtain a 1 L sample. Moisture was added to each sample to obtain 6% and 28% moisture by weight for the corn grits and vermiculite, respectively. Previous tests indicated an improvement in the flow properties of these carrier materials with increased moisture content. Two runs were made for each carrier material. Each run contained 500 mL of mite-carrier material which was placed in a 3 in wide x 10 in diameter container. The container was chucked into a lathe and rotated at 12 RPM. Fifty mL samples were taken 1, 2, 4, 8, 16, 32, 64, and 128 minutes of tumbling time. A 50 mL control sample was taken prior to each run. Mite survivability was determined by counting the live mites as previously described.

Results & Discussion

Blower - Laboratory Tests

The results for test 1 are shown in Table 1. The low mite recovery (17.8%) and high variability (31.0%) indicate the possibility of several factors that are difficult to explain. One major concern is the distribution pattern of mites. When mites and carrier are metered into the air stream a question arises whether they attach themselves to the carrier particles and are dispersed accordingly, or are unattached and free to float in the air stream. The process of metering and introducing the mites into the high velocity airstream may have caused dismembering resulting in identification problems. Some mites may have been lost because the capture surface area was of insufficient size, particularly if the mites float freely in the air stream.

Mite recovery for tests 2, 3, and 4 is shown in Table 1. Again, the results are highly variable and difficult to explain. The metering device is the only difference between tests 2 and 3, but the results differ. The mite recovery rate for tests 1 and 3 is similar, but the metering devices differ. Test 4 had the highest mite recovery rate (55.1%) and was the only one with vermiculite as a carrier. The 3-slot metering device was not tested with the vermiculite carrier because the particle size is too large for the slots. No conclusions can be made with regard to the effect of the metering devices or mite-carrier materials tested with respect to mite recovery.

The distribution of mites for tests 2, 3, and 4 with respect to their longitudinal and transverse locations from the blower discharge, is shown in Figs. 1-6. A comparison of the distribution in the longitudinal direction for tests 2 and 3 (Figs. 1 and 3, respectively) indicates a wider range of distribution (10- 45 ft) of live mites for test 2 than the 20 ft to 35 ft range for test 3. Since the only difference between tests 2 and 3 is the metering devices, they appear to have an effect on the mite longitudinal distribution. The range of transverse locations of live mites between tests 2 and 3 (Figs. 2 and 4, respectively) are similar and does not appear to be affected by the metering devices.

Tests 3 and 4 have the same 1-slot metering device, but a different mite carrier. A comparison of the distribution in the longitudinal direction for tests 3 and 4 (Figs. 3 and 5, respectively) indicates a wider range of distribution (15-45 ft) of live mites for test 4 than the 20 ft to 35 ft range for test 3. A comparison of the distribution in the transverse direction for tests 3 and 4 (Figs. 4 and 6, respectively) show little difference. It's difficult to conclude what effect, if any , that the metering devices had on either mite recovery or distribution for these tests, but it does appear that the mite-carrier material may affect the recovery rate.

Blower - Field Tests

The 1995 test results indicate a live mite recovery rate of 94.8% average for the four plots. Sampling was done one day after mite application. These results appear to be consistent with observations of 1993 field application studies where the predaceous mite population overwhelmed the check plots and adjacent fields. However, the results appear to be optimistic based upon survival studies and other experiences with this delivery system. The positive aspect of this test is, although the data is questionable, there were factual results. The average mite density (mites/sq ft) within each 10 ft, 20 ft, and 30 ft radius semicircle areas was 4.19, 2.28, and 3.37 respectively, for the four plots. This data suggests the distribution of predaceous mites may be reasonably uniform with this delivery system.

The 1996 test results were a complete failure in that essentially no predaceous mites could be found when sampled one day after application. This inconsistency in test results is very difficult to explain but suggests caution in developing a ram-venturi meter and delivery system for predaceous mites. Field applications with this system are highly dependent upon climatic conditions. Wind velocities greater than about 1-2 mph have a severe effect on the distribution pattern. In many areas, field operations would be limited to the calmest part of the day which is usually just prior to sunrise.

Other Metering Devices & Tests

Auger

Mite survival averaged 84.7% for the five samples evaluated for the auger (Table 1). The data was quite uniform with a coefficient of variability of 8.3%. During testing, the power requirements to rotate the auger appeared to vary. Although it was not measured , power needs seemed to increase whenever the mite-carrier material was trapped between the leading edge of the auger flight and the auger housing. It is conceivable that mite injury occurred during these instances.

Belt

Mite survival averaged 92.5% for the ten samples evaluated for the belt meter (Table 1). The coefficient of variability (27.9%) was quite high for these samples. The only explanation is that possibly the mites were not uniformly mixed in the carrier material. This relatively high survival rate and the potential for variable rate delivery place this belt meter technology as the most practical for development.

Tumbling Test

Mite survival with respect to tumbling time is shown in Fig. 7 for two carrier materials. Vermiculite appears to be the better of the two carrier materials for mite survival throughout the entire test period Mite survival diminishes rapidly after 8 minutes of tumbling time for both carrier materials. Based upon these results mites tumbled for longer than 30 minutes (equivalent to 360 revolutions) have a survival rate of about 28% in corn grit and 44% in vermiculite. The initial mixing of the mites and carrier material should be minimal in order to abate mite mortality.

It appears that tumbling mites for maintaining a uniform mixture with a carrier material is not practical because of the need to replenish the supply every 15-30 minutes. This would not be practical as field efficiency would be very low.

Summary

The ram-venturi metering system is unacceptable for distributing predaceous mites. This conclusion is based upon the unexplained inconsistencies of mite survival and distribution. The dependency of field operations on unpredictable climatic conditions further substantiate this conclusion.

A mite metering system that depends on tumbling to maintain uniformity in the mite-carrier mixture is unacceptable. Mite survivability after 8 minutes (equivalent to 96 revolutions) of tumbling decreased very rapidly. Caution should be exercised to minimize the mixing and dilution of the initial mite-carrier material obtained from the insectary. Giles, 1995 conclusion that the most practical method of maintaining a uniform mixture was to immobilize the mites by keeping the mixture at a temperature of 2° C appears to be very appropriate.

Both the auger and belt metering devices show good potential for metering mites. The belt system is more adaptable to low metering rates and has a more uniform power requirement.

Based upon data from these various tests, a prototype belt metering system is being constructed for further testing. A insulated container with gel-ice as a coolant was designed to interface with the system.

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Table 1. Live Mite Capture Tests

Test	Meter	Recovery %	CV (%)
Blower #1	3-slot	17.8	31.0
Blower #2	3-slot	32.0	
Blower #3	1-slot	17.5	
Blower #4	1-slot	55.1	
Auger	3/4" orifice	84.7	8.3
Belt	5/16"x3/4" slot	92.5	28.0

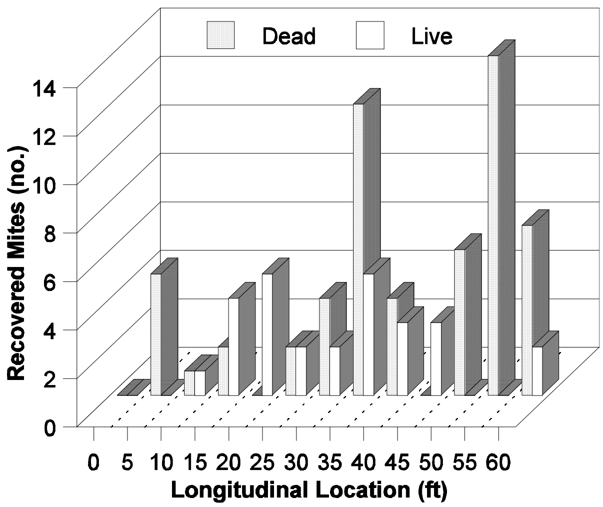

Figure 1. Longitudinal distribution of predaceous mites in test no. 2.

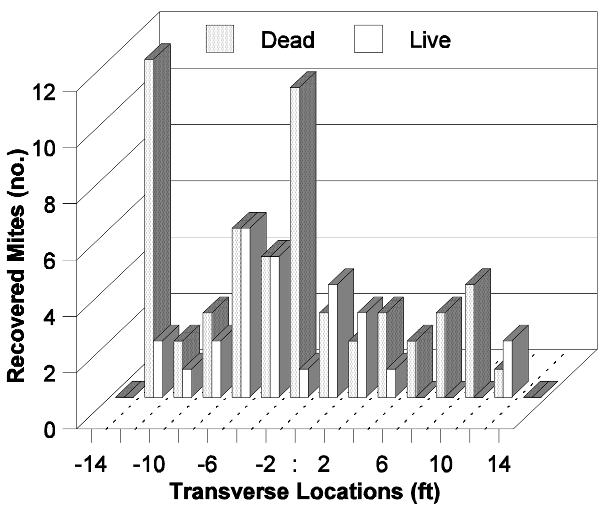

Figure 2. Transverse distribution of predaceous mites in test no. 2.

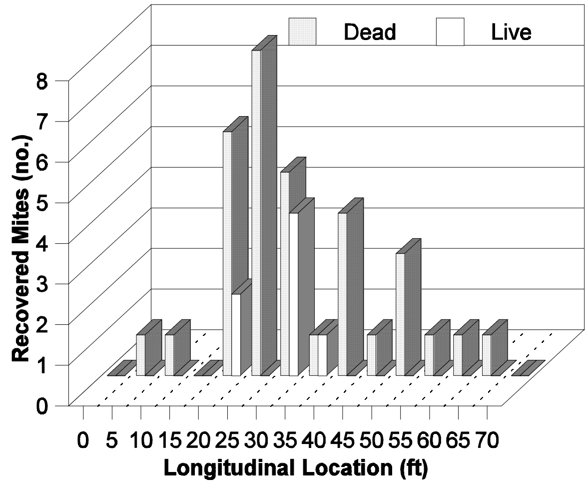

Figure 3.Longitudinal distribution of predaceous mites in test no. 3.

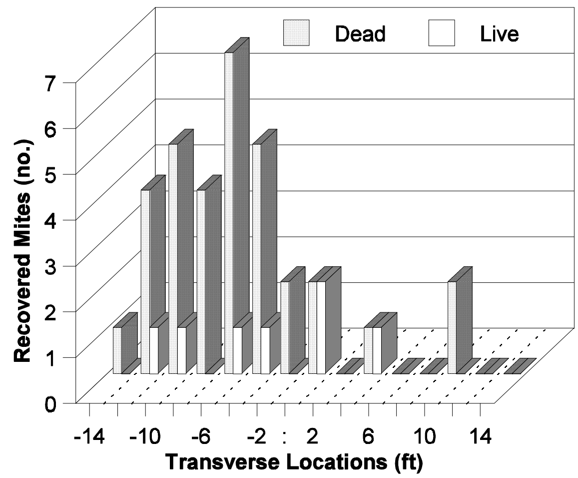

Figure 4.Transverse distribution of predaceous mites in test no. 3.

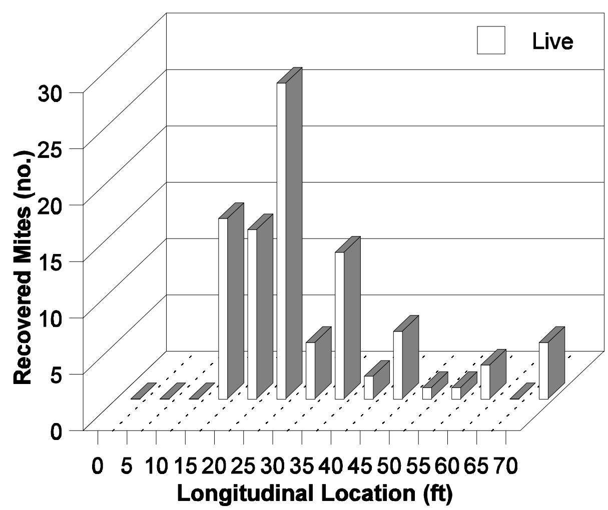

Figure 5. Longitudinal distribution of predaceous mites in test no. 4.

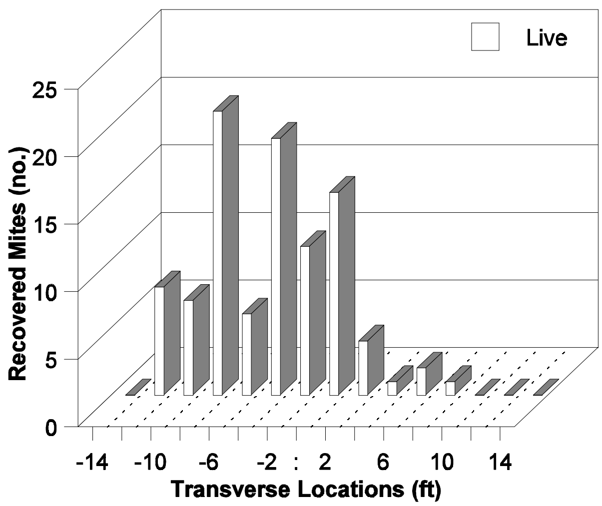

Figure 6.Transverse distribution of predaceous mites in test no. 4.

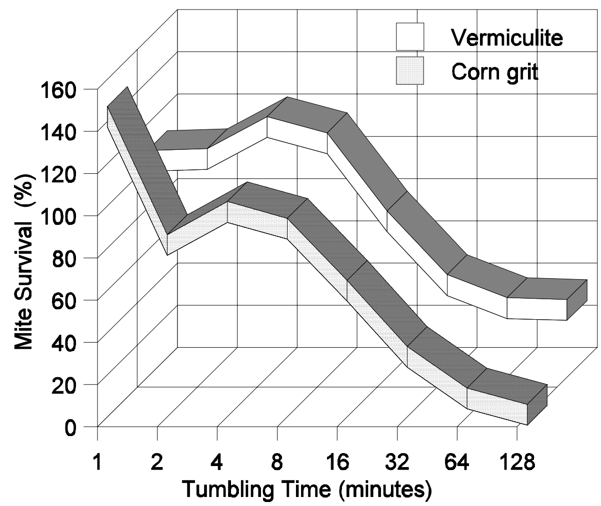

Figure 7. Effect of tumbling on predaceous mite survival with two carrier materials.