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IMPACT OF THERMAL COTTON DEFOLIATION ON LATE-SEASON INSECT POPULATIONS

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Abstract

The potential impact of heat mortality as part of thermal cotton defoliation was evaluated in comparison to chemical defoliation and an untreated check for silverleaf whitefly immatures and adults at two sites in New Mexico. Adult whitefly emergence was significantly less for leaves exposed to a thermal treatment than the chemical or untreated checks. In the field, whitefly populations in the thermal plots were reduced to near zero immediately after defoliation where they remained throughout the study. Whitefly populations in chemically-defoliated plots closely resembled that of the untreated checks, likely due to the late-season conditions of the plants and not an impact of defoliation. The relative maximum temperatures attained and heat units accumulated by thermal defoliation were compared at various locations within the canopy.

Introduction

The silverleaf whitefly, *Bemisia argentifolii* (Bellows and Perring), and cotton aphid, *Aphis gossypii* (Glover), are pests of significant concern for cotton production in the U.S. Late-season populations of these insects are particularly damaging because honeydew accumulation on open bolls results in sticky cotton, which reduces fiber quality and causes serious problems in spinning mills (Hequet and Abidi 2002). Areas experiencing even a single event of sticky cotton have experienced depressed cotton market value for years following (Ellsworth et. al. 1999).

Thermal defoliation of cotton was first investigated over fifty years ago (Funk 2004). Recently, Funk et al. (2004) showed that thermal defoliation does work for both pima and upland cotton varieties. Thermal defoliation is of interest to the organic cotton market because chemical defoliants are not allowed for use in crops certified as organic, and because the general public perceives that chemicals might be harmful to the environment. Another potential application is for growers requiring immediate removal of a crop to prevent loss as a result of bad weather. Funk et al. (2004) found that at two days after thermal treatment, cotton plants were sufficiently desiccated for harvesting.

While conducting thermal defoliation experiments, anecdotal evidence of insect mortality was frequently observed. This contrasted with chemical defoliation, after which insect populations temporarily increased following treatment (Funk, unpublished data). Defoliant-induced stress may draw insects by increasing plant sap free amino acid levels, if plant physiologic response to defoliants is similar to drought response (Showler et al. 2003).

The current research was initiated to investigate two objectives: 1) to determine the relative impacts of thermal vs. chemical defoliation on late-season whitefly populations and 2) to document the thermal levels attained on the cotton plants.

Materials and Methods

Cotton for this research was planted in early May at the Leyendecker Plant Science Research Center near Las Cruces, New Mexico. Both fields (~3 acres, each) were transgenic Bt. The primary field (field 1) was planted to widestrike cotton (PhytoGen 1517-99W). A second field (field 2, DP 449 BR) was used due to high whitefly populations. The thermal defoliation studies were initiated in each field when cotton averaged ~80% open bolls.

Thermal Defoliation Apparatus
The two-row prototype thermal defoliator heated air to 193°C (380°F) using a propane burner. Fans forced the heated air through the cotton canopy. Two tanks with a combined nominal capacity of 606 l (160 gal) provided approximately eight hours of fuel for both the burner and engine. At 1.6 kmh^{-1} (1 mph), the fifteen foot long treatment chamber exposed plants to hot air for approximately ten seconds. Figure 1 shows the apparatus.

Objective 1 (Whitefly evaluations)
The impact of thermal defoliation on silverleaf whitefly populations was evaluated in the field in a two-part experiment. Each field was given three treatments: thermal defoliation, chemical defoliation, and untreated check. Thermal defoliation was performed in 2-row strips; chemical defoliation (Folex), at the high labeled rate of 2 pts/acre, was applied in 4-row strips; and the untreated check consisted of 3 row strips. Each treatment was separated by at least 2 border rows. Field 1 was known to have some variability in soil type, so samples were taken from both the sandy and clay regions. The soil type in field 2 was uniform, so a single region of the field was sampled. Immediately after defoliation, twenty upper and lower leaves were removed from randomly-selected plants within each treatment, placed in Petri dishes lined with moistened filter paper, and taken to the laboratory. Leaves were maintained in an incubator at 25 °C under a photoperiod of 14:10 LD for 1 week. At this time, the total number of pupae and the number of eclosed adults were recorded for each leaf to determine the percentage of emerging adults for each treatment. Data were analyzed using PROC MIXED procedure of SAS (2003). Since this was significant, an LS mean test (Tukey-Kramer) was performed.

Field mortality of whiteflies also was assessed after defoliation treatments to determine the potential impacts of recolonization. Five randomly-selected upper and lower leaves from each plot (+ soil type in field 1) were flagged, and the numbers of nymphal/pupal and adult whiteflies, and cotton aphids were recorded. Leaves were examined daily until leaves dropped from the plants in the thermal and chemical treatments. Data were analyzed using a repeated measures analysis of variance. There were significant time by treatment interactions. Therefore, treatment differences were tested for each day. A 2 degree of freedom test was run to detect overall differences in treatment means each day; if this test was significant ($\alpha=0.05$), a subsequent mean separation (t-test) was conducted.

Objective 2 (Plant thermal evaluation)
To determine the levels of heat produced in the thermal defoliation process in the field, three randomly-selected plants were fitted with twenty ultra fine thermocouple wires recorded by a data logger (Agilent 34970A). On each plant, temperatures were evaluated in both the upper and lower canopy for lower leaf surface, surface of a closed boll, and lint of an open boll; air temperature and soil surface temperature also were recorded. Each junction was repeatedly scanned while the defoliation machine passed over, measuring the extent and duration of temperature rise at those locations on the plant. This process was replicated for a total of twelve times (36 plants) at two locations.

Results

Whitefly evaluations
There was a significant treatment effect for the percentages of emerging adult whiteflies after defoliation ($p<0.0001$). Adult emergence was least for the thermal treatment and greatest for the chemical treatment (Fig. 2). However, no differences were observed for upper versus lower leaves.

In field one, cotton in the sandy plots was much smaller than that of the clay plots and was obviously water stressed; therefore, data for those plots will not be discussed here. Whiteflies populations were relatively low at the field one site, with nymphal/pupal populations averaging 3.5 per leaf (lower) and ~6 per leaf (upper). For immatures, the number of living individuals in all thermal plots dropped immediately after defoliation and remained near zero for the remainder of the study. Populations in both the chemical treatment and control began to decline after defoliation until ~7-9 days after defoliation, at which time they leveled off or increased slightly. There were significant date by treatment interactions. Immature whitefly populations were significantly lower in the thermal treatment than the chemical or control treatments immediately after defoliation until 7 days after defoliation. At this point, whitefly numbers in the controls for upper leaves were not significantly different from that of the thermal treatment ($p=0.0521$), and there was no significant difference among treatments for upper leaves. The thermal treatment was again significantly lower than the other treatments until day 13 for upper leaves and day 14 for lower leaves (Fig. 3).

In field two, whitefly populations were much higher, with nymphal/pupal numbers averaging 48 per leaf (lower) and ~55 per leaf (upper). As in field one, immature populations dropped immediately after defoliation and remained at or near zero for the remainder of the study (Fig. 4). Populations of whiteflies on lower leaves in the chemical and control began a gradual decline shortly after defoliation. Whitefly immatures on upper leaves of the chemical and control treatments appeared to increase somewhat for the first few days after defoliation before gradually declining, and there was a sharp peak in whitefly immature numbers for the chemical treatment on day 8 after defoliation. As in field one there were significant date by treatment interactions. For lower leaves, whitefly numbers in the thermal treatment were significantly lower than the other treatments until 9 days after defoliation when there was no statistical difference between thermal and chemical treatments. By 12 days after defoliation, there were no differences among treatment. For upper leaves, the thermal treatment was significantly lower than the other treatments until 9 days after defoliation, with the exceptions of day 3 and day 7 when it was statistically similar to the chemical treatment. By day 9, there was no difference among treatments.

Adult whitefly populations in field one dropped to zero immediately after defoliation, where they remained throughout the study. Numbers of adults in the chemical treatments were similar to the control after defoliation (Fig. 5). Adult population data for field two remains to be analyzed.

Plant thermal evaluation

The maximum temperatures reached as part of thermal defoliation appear to be somewhat higher for upper leaves than lower ones (Table 1). The average maximum leaf surface temperature was 234°F for upper leaves and 194°F for lower leaves. Temperatures for lint of open bolls reached ~140°F, and boll surface temperatures reached an average maximum of ~145°F. Because thermal lethality is a combination of time and temperature, heat units were defined for this experiment as degree seconds above 165°F. Again, there were differences between plant parts and elevation. Leaf surfaces experienced ~550 to 240 degree seconds in the upper and lower plant canopy respectively. Boll surfaces and lint in open bolls were more protected, enduring 164 degree seconds or less. Future research is planned to determine the heat units necessary to kill aphids and whiteflies at various stages of development.

Table 1. Maximum temperature and heat units attained during thermal defoliation.

Elevation	Location	Maximum Temperature (°F)	Heat Units (°F-sec)
Upper	Leaf	234 a	551 a
	Lint	144 b	164 b
	Boll	159 b	100 b
Lower	Leaf	194 a	240 a
	Lint	138 b	154 ab
	Boll	130 b	4 b

Means with the same letter are not statistically different.

Conclusions

Thermal defoliation appears to have an immediate impact on whitefly populations. Temperatures in the field appeared sufficient to cause death of immature whiteflies on leaves in both the upper and lower portions of the plant. No recolonization of thermally-defoliated plants was observed. Leaves from these plants were noticeably desiccated within 24 hrs and could not support the insects. Whitefly populations in conventional chemically-defoliated plots closely resembled that of the untreated checks, and both treatments showed a similar decline in whiteflies after defoliation. This is likely due to the late-season conditions of the plants and not an impact of defoliation. Although there were certain days after defoliation when the thermal treatment was not significantly different from the chemical treatment, populations in the latter plots were well above economic threshold levels –particularly in field two –and still would result in accumulation of sticky cotton. Much information is still lacking on potential lethal and sublethal effects of heat on late-season pests of cotton. Future research is planned to determine the heat units necessary to kill aphids and whiteflies at various stages of development.

References

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Figure 1. Apparatus used to apply thermal treatment.

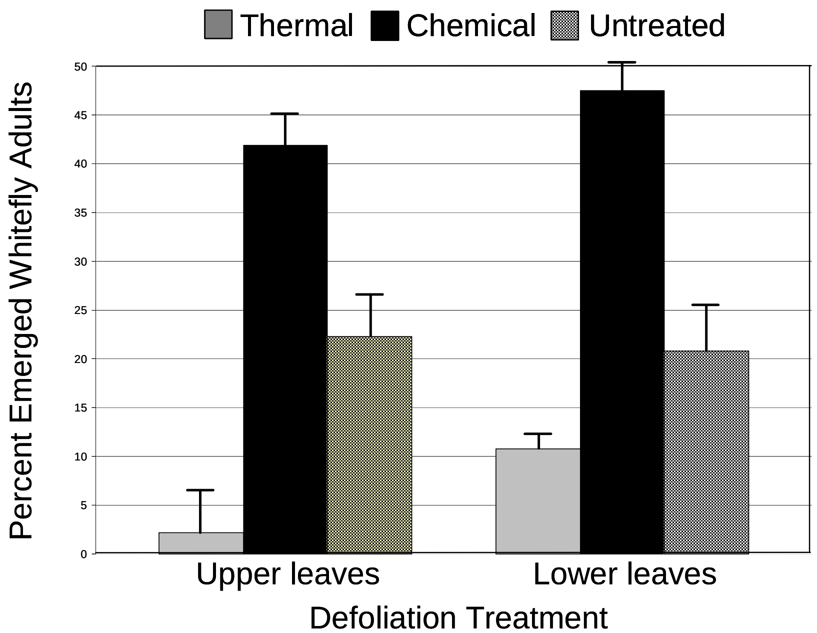

Figure 2. Mean percentage of adult whitefly emergence per leaf after defoliation treatments.

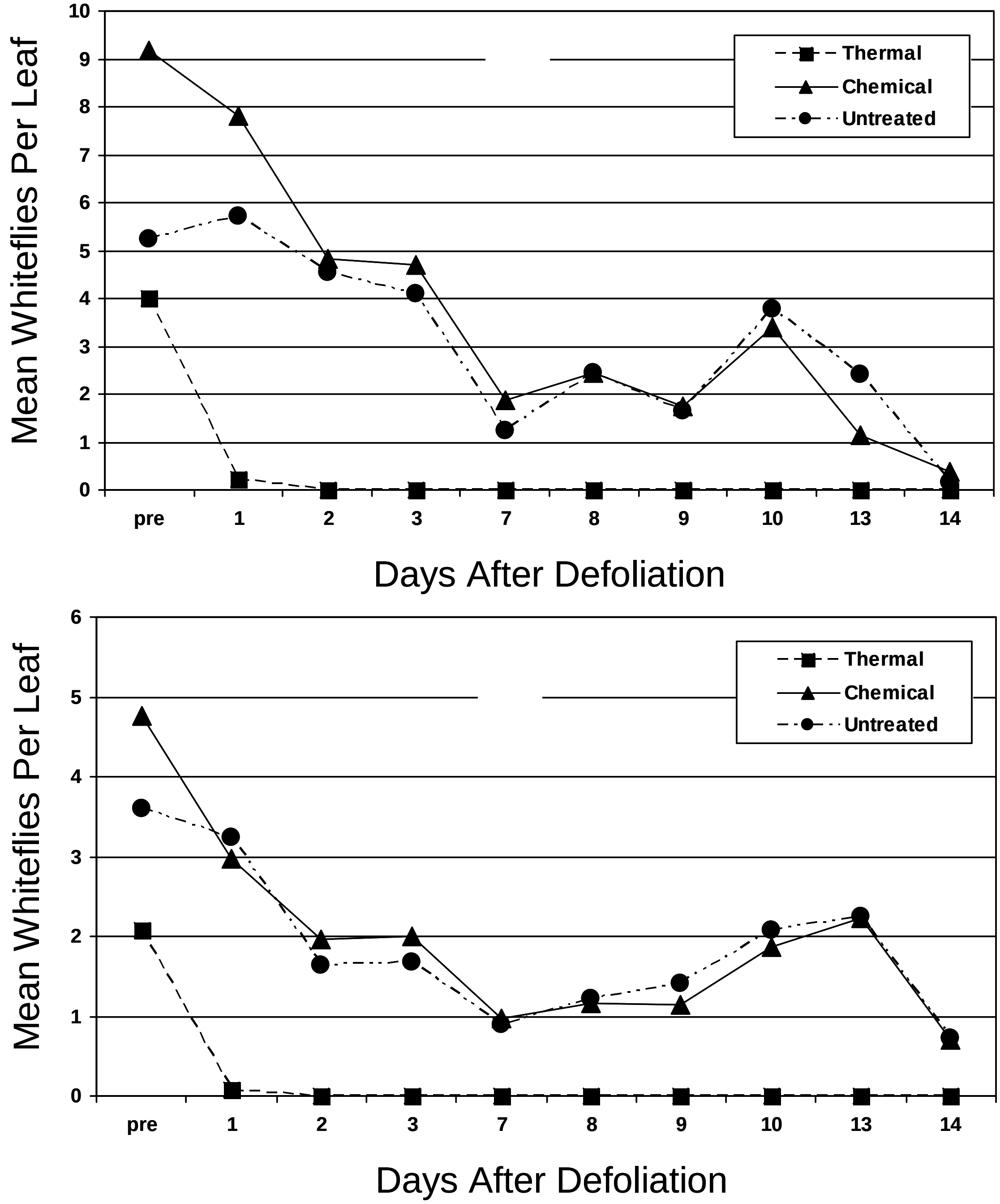

Figure 3. Mean immature silverleaf whiteflies per leaf at field 1 after defoliation treatments. A) upper leaves, B) lower leaves.

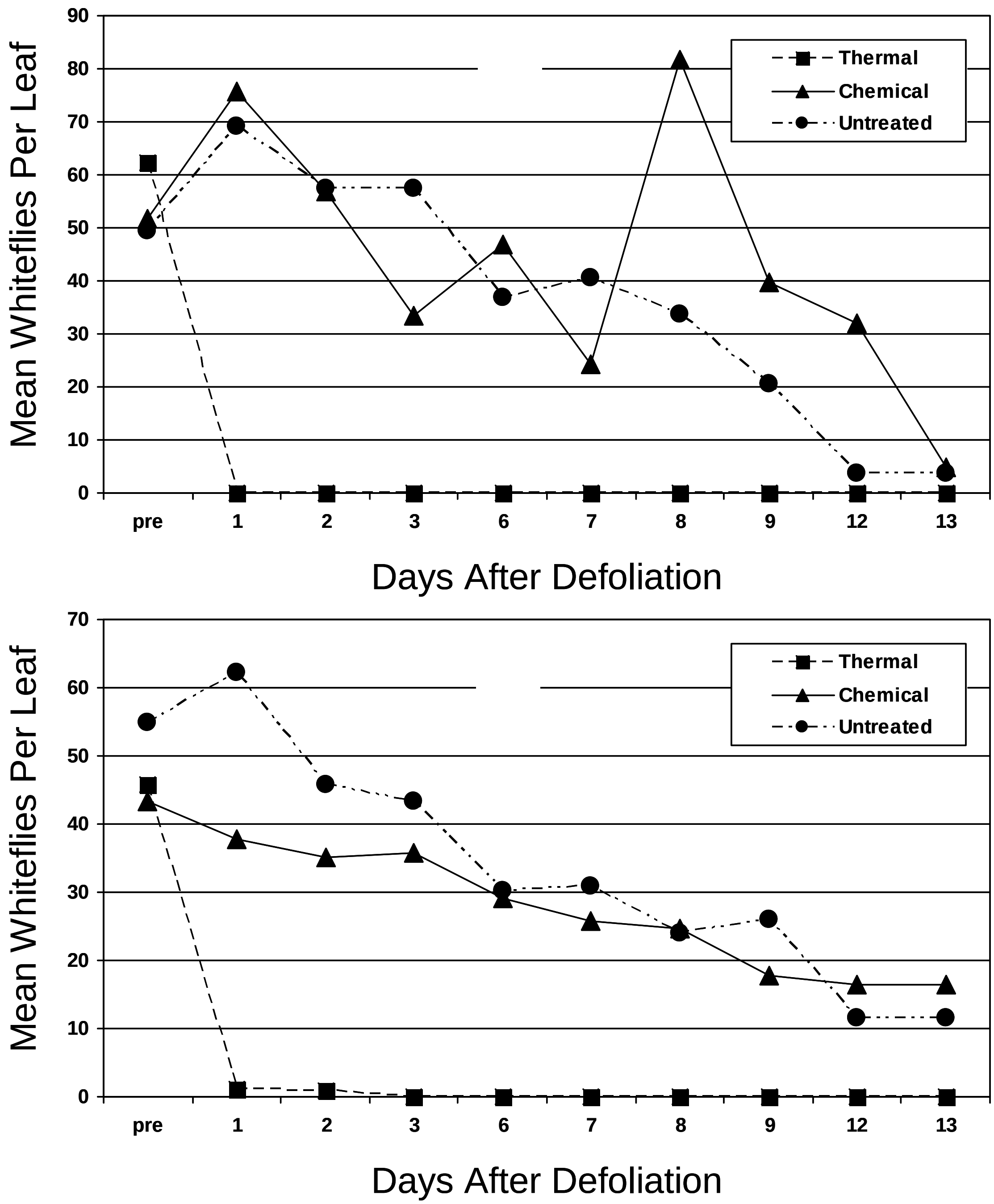

Figure 4. Mean immature silverleaf whiteflies per leaf at field 2 after defoliation treatments. A) upper leaves, B) lower leaves.

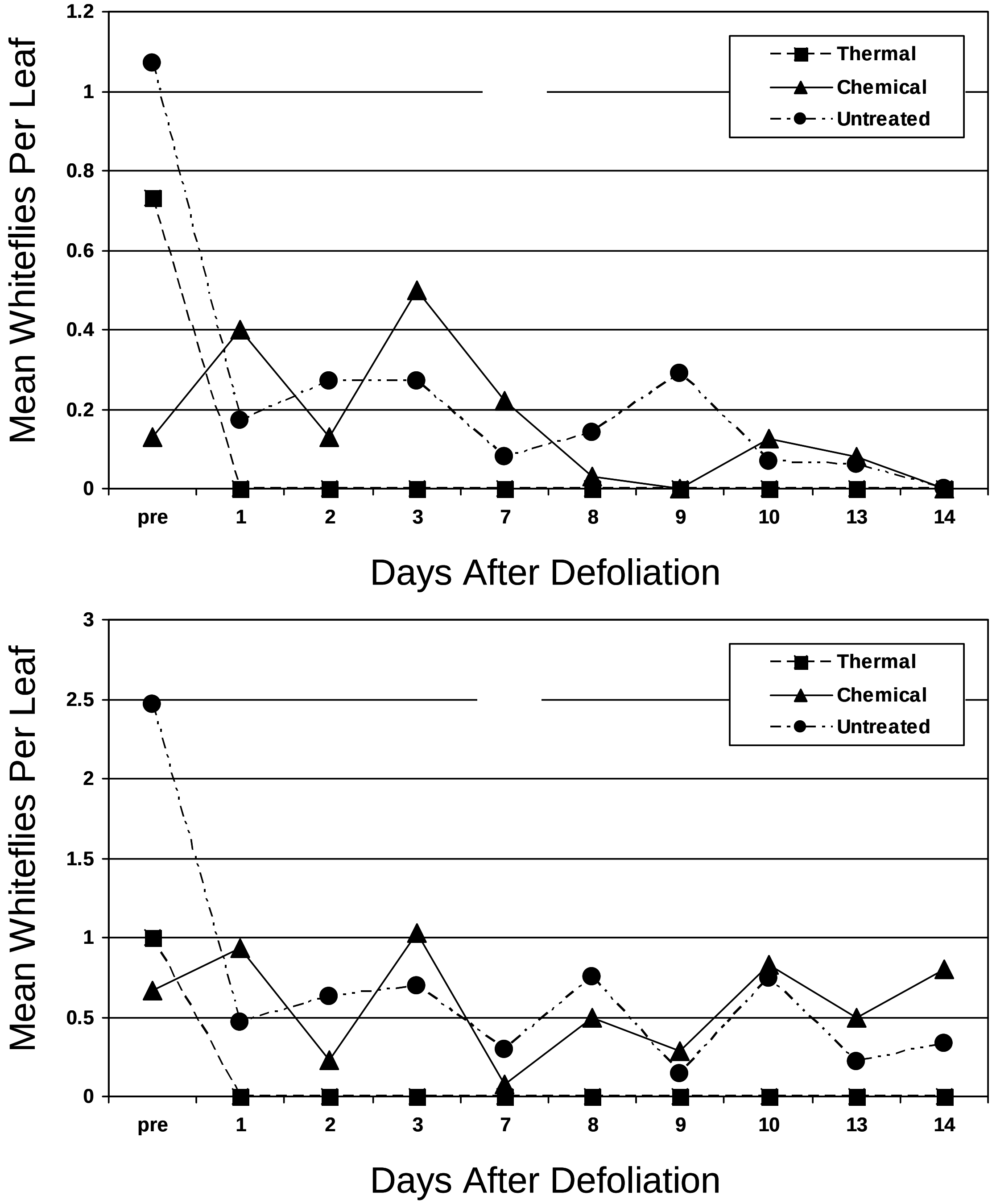

Figure 5. Mean adult silverleaf whiteflies per leaf at field 1 after defoliation treatments. A) upper leaves, B) lower leaves.