PEST MANAGEMENT GRANTS FINAL REPORT

TITLE: Integrated Management of Soil Borne Diseases and Aphid Transmitted Viruses in California Vegetable Crops--An on Farm Demonstration

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Abstract

Aphid transmitted viruses cause serious losses in a number of vegetable crops (squash, pumpkin, cucumber, cantaloupe, corn, tomatoes, eggplant, pepper, and broccoli) throughout the San Joaquin Valley. Most vegetable lake resistance to these viruses and attempts to control the disease by controlling the aphids with insecticides are generally unsuccessful. The recent introduction of the silverleaf whitefly into the San Joaquin Valley has also made vegetable growing, particularly in the fall, next to impossible. In our studies, vegetables were planted into reflective plastic mulch (referred to as metalized mulch and manufactured by applying a thin layer of aluminum to polyethylene) placed over the beds prior to planting. Both replicated small plot studies and large non-replicated grower cooperator trials were conducted. We found that growing vegetables over reflective mulch significantly reduced both the incidence and severity of aphid-borne virus diseases. Plant remained virus free for 2-6 weeks longer than did plants grown over bare soil. In addition fewer plants became virus infected. Plants growing over reflective mulch produced marketable fruit 7 to 10 days earlier than plants growing over bare soil. Yields from plants growing over reflective mulch were significantly higher that from those growing over bare soil. We also found that the reflective plastic mulch both reduced the incidence and severity of colonization by the silverleaf whitefly resulting in significantly increased yields. In many situations, the use of reflective mulch alone provided more control of silverleaf whitefly than did the use of insecticide. In addition to reduced aphid infestation, virus disease incidence, and silverleaf whitefly numbers, reflective mulches reduced the incidence and severity of potato leafhopper, corn stunt leafhopper, lygus bugs, and leaf miners.

Executive Summary

Production of many vegetable crops in the San Joaquin Valley of California is severely limited by a number of aphid-borne virus diseases. This is particularly true in fall planted vegetables. Insecticides are on little or no use since the viruses can be acquired and transmitted in a matter of seconds by the aphid vector. In many situations, the use of insecticides actually results in an increase in the rapidity with which these viruses are spread. More recently (early 1990's) the silverleaf whitefly was introduced into the southern San Joaquin Valley. Populations built throughout the summer and by late summer or early fall, densities and sufficient to make growing some vegetables nearly impossible. This insect develops resistance to insecticides very rapidly and is extremely difficult to control. The combination of these two entities have severely curtailed the fall vegetable production in the San Joaquin Valley and, in some situations, has lead to a complete abandonment of the effort.

Reflective mulches have been used successfully to reduce the incidence of aphid-borne virus diseased in squash and other crops. By repelling the aphids, the cycle of transmission is interrupted and infection fails to occur or is delayed by a sufficient length of time to permit the maturation of a normal crop. The incidence of virus diseases can be reduced significantly without the need for chemical pesticide. Reflective mulches have also been shown by work supported by DPR in the project to be repellent to silverleaf whiteflies and through their use, a crop can be matured and harvested with little or not need for insecticides. The use of polyethylene mulches also provides excellent weed control reducing the reliance on herbicides. They also conserve water, resulting in reduced irrigation requirements and the expenditures of energy associated with irrigation. This has been demonstrated both in small replicated plots at the Kearney Agricultural Center and in large grower cooperator trials.

The present study was designed to further investigate the used of reflective plastic mulch for managing a wide range of Homoptera attacking vegetable crops in the San Joaquin Valley. We also worked closely with growers in the area to both evaluated this strategy in a large scale on farm operation and to demonstrate to the growers the utility of using reflective mulches for the management of these insects and diseases. We also demonstrated the utility of these mulches in reducing water requirements and in controlling weeds, thus reducing the need for herbicides under many conditions.

More recently a great deal of interest has developed in the area of conservation tillage and the use of cover crops into which vegetable are either seeded or transplanted. The theory behind the use of cover crops is that tillage is reduced, the cover crops adds tilth and structure to the soil and helps open compacted soils, the cover prevents the germination and growth of weeds, legumes such as vetch add nitrogen to the soil and the decomposing crops itself adds long term nitrogen to the soil.

Small plot studies were conducted at the Kearney Agricultural Center, Parlier CA. Tomatoes, squash, eggplant, and corn were evaluated in replicated trials. Pumpkins were evaluated in grower cooperator studies.

In tomatoes, three production systems were evaluated using fresh market tomatoes. These includes 1) growing plants over a cover crop that has been killed and rolled flat on top of the beds. 2) growing plants over reflective plastic mulch. 3) Growing plants over fallow bets--conventional production. A spring and summer planting were evaluated. Early in the season, more aphids were found on plants grown under conventional tillage but as the season progressed, the numbers found in the cover crop plots and the conventional plots were significantly higher than those found on plants grown over reflective mulches. By the end of the season as harvest approached, plants growing over the reflective mulches had accumulated 2.5 X the biomass of plants growing under the other production systems. The larger, more robust plants growing over reflective mulch produced significantly higher yield. In the summer planting, plants growing over the reflective mulches accumulated significantly more biomass, and a an earlier stage of growth than did plants growing under the other production systems. Both the cover crop and the reflective mulch were effective in suppressing weed growth. The sorghum-sudan hybrid we chose as the cove crop turned out to be alleopathic to tomatoes.

We evaluated a multiple management system in squash for aphid, virus, and whitefly management using reflective mulch, virus resistant varieties, and a per-plant Admire ® . The incidence of aphid-borne virus diseases was most reduced by the use of reflective mulch, followed by the use of resistant varieties, and finally, the application of Admire. The incidence of squash silverleaf was most impacted by reflective mulch. Only reflective mulch produced a significantly higher yield. All other treatments were similar in yield. We also evaluated several new reflective mulches. All worked similar to those we had already tested and all resulted in significantly fewer aphids, silverleaf whiteflies, and less virus than found in plants growing over bare soil or treated with insecticide. Although we have observed that squash plants growing over reflective mulch grow more rapidly, accumulate more biomass, and produce fruit earlier than plants growing over bare soil, these facts have never been documented. We conducted an experiment with two treatments: 1) plants grown over reflective mulch, 2) plants grown over bare soil. Plants growing over reflective mulch clearly accumulated more foliage, root, and reproductive tissues biomass at a more rapid rate and earlier than did plants growing over bare soil. Studies in a grower field of pumpkins showed that yields from plants growing over reflective mulch were 2 to 5 times higher than from plants growing over fallow beds. Studies such as these support the notion at reflective mulches not only work in small experimental plots but also work under larger commercial production.

In eggplant, a new unidentified malady appears to be affecting eggplant in the San Joaquin Valley. At this point, the malady remains unidentified. We are working to establish its identity, causal agent, and vector, if any. We evaluated reflective mulch and two insecticides applied immediately after transplanting. Yields were significantly higher in plants growing over reflective mulch.

The incidence of corn stunt disease was significantly reduced in plants growing over reflective mulch. Neither a per-plant insecticide treatment or a post-emergence foliar treatment reduced the incidence of this disease. Yields were also higher in plants growing over reflective mulch. This study is the third in three years in which the incidence of corn stunt disease has been significantly reduced in plants growing over reflective mulches. This confirm that reflective mulches repel the leafhopper vector of this disease. This is the first definitive work showing that reflective mulches repel leafhoppers.

Synopsis of Three Year Progress

Production of many vegetable crops in the San Joaquin Valley of California is severely limited by a number of aphid-borne virus diseases. This is particularly true in fall planted vegetables. Insecticides are on little or no use since the viruses can be acquired and transmitted in a matter of seconds by the aphid vector. In many situations, the use of insecticides actually results in an increase in the rapidity with which these viruses are spread. More recently (early 1990's) the silverleaf whitefly was introduced into the southern San Joaquin Valley. Populations built throughout the summer and by late summer or early fall, densities and sufficient to make growing some vegetables nearly impossible. This insect develops resistance to insecticides very rapidly and is extremely difficult to control. The combination of these two entities have severely curtailed the fall vegetable production in the San Joaquin Valley and, in some situations, has lead to a complete abandonment of the effort. Reflective mulches have been used successfully to reduce the incidence of aphid-borne virus diseased in squash and other crops. By repelling the aphids, the cycle of transmission is interrupted and infection fails to occur or is delayed by a sufficient length of time to permit the maturation of a normal crop. The incidence of virus diseases can be reduced significantly without the need for chemical pesticide. Reflective mulches have also been shown by work supported by DPR to be repellent to silverleaf whiteflies and through their use, a crop can be matured and harvested with little or not need for insecticides. The use of polyethylene mulches also provides excellent weed control reducing the reliance on herbicides. They also conserve water, resulting in reduced irrigation requirements and the expenditures of energy associated with irrigation. This has been demonstrated both in small replicated plots at the Kearney Agricultural Center. We also worked closely with growers in the area to both evaluated this strategy in a large scale on farm operation and to demonstrate to the growers the utility of using reflective mulches for the management of these insects and diseases. More recently a great deal of interest has developed in the area of conservation tillage and the use of cover crops into which vegetable are either seeded or transplanted.

Silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring, and melon aphid, *Aphis gossypii* Glover, are pests of vegetables in the San Joaquin Valley of California. Melon aphid attacks cucurbits, while silverleaf whitefly impacts cucurbit, solanaceous, and cruciferous crops. Melon aphid also transmits several viruses, which often cause complete crop failure, in cucurbits. Insecticides are ineffective, particularly for control of the aphid-borne viruses. We found that metalized and silver embossed plastic mulches were effective in both reducing and delaying colonization and buildup of whiteflies and aphids, and reducing and delaying the incidence of aphid-borne viruses. In our experiments, plants were grown on raised beds over which the mulches had been placed and secured with soil. Plots consisted of three planting beds, 7.5-m long, with each mulch replicated six times in a randomized block design. The width of individual planting beds varied depending on the crop grown. Metalized reflective mulch was also evaluated in 2 ha grower fields of cucumber, pumpkin, and zucchini squash. Adult whiteflies and alate aphid populations were determined by counting the number of individuals on the newest fully expanded leaf on each plant in the center plot row. Density of immatures was determined by returning a leaf from each plant to the laboratory and counting the number of individuals present. Fruit was harvested from the center row of each plot, weighed, and graded. Data were evaluated by ANOVA and Fisher's LSD. In cantaloupe (Photo 5) and cucumbers, reflective mulches reduced alighting by alate aphids and delayed the incidence of aphid-borne viruses by six weeks. Aphid and whitefly numbers and the incidence virus infected plants were lower and yields higher in plants grown over reflective mulches. Yields from mulched plots were

200 to 300% higher than those from unmulched plots. In grower trials, aphid and whitefly numbers and the incidence of squash silverleaf were significantly lower and yields significantly higher in cucumber, pumpkin, and squash grown over metalized reflective mulches. In sweet corn, metalized mulches repelled the corn stunt leafhopper, *Dalbulus maidis* (DeLong and Wolcott), resulting in a significant reduction in the incidence of corn stunt disease, caused by *Spiroplasma* sp., and produced significantly higher yields.

Growing broccoli over reflective mulch reduced the incidence of both eggs and nymphs on the plants. Yields from broccoli plants grown over reflective mulches were twice those from plants grown over bare soil. This was in response both the whitefly feeding pressure and to enhanced growth provided by the plastics. Maturity in bare soil plots was delayed by several weeks.

A pilot study on the effects of solarization and reflective mulches on summer field production of cut flowers (zinnia) was initiated in 1997. Treatments included reflective mulch, shade fabric covers, and bare soil. Preliminary results of two planting dates showed that flowers grown over reflective mulches produced an average of 40% more flower stems than those grown over bare soil. Flower production was highest in the absence of shade cloth.

Throughout the project, one of our most important goals was to impart the information that we developed through experimentation to the growers of the San Joaquin Valley. We also considered instruction in the proper use of these reflective mulches to be an important goal. To this end, we held numerous field days and workshop each year to deliver this information to the growers. During the course of the study, now fewer that 12 workshops/field days were held. In addition, we demonstrated the information developed to a wider audience by presenting talks, not only on a statewide basis, but to a worldwide forum. These talks were delivered both to growers groups and to scientific societies. We published the results of our finding widely. Again, information was disseminated both to the growers and to learned societies. We have published much of our finding in the UC IPM Pest Management Guidelines. We have also published extensively in the scientific literature. No fewer that a dozen articles have appeared in the farm press detaining the results of our studies. We have also given numerous radio and television interviews.

1999 Progress Report

Introduction and Scope of Project:

Background and Previous Work: Aphid transmitted virus diseases cause significant economic losses to California's multimillion vegetable crop annually. In the past several years, production of fall melons (cantaloupe, honeydew and mixed melons), squash (zucchini, crookneck and hard winter squash), peppers (bell and chili) and tomatoes (fresh market and processing) has been virtually impossible in the SJV due to extensive virus epidemics. Spring crops, while affected to a lesser extent, have also suffered significant losses due to aphid transmitted viruses.

Several plant viruses are responsible for these epidemics and most are capable of infecting all of the crops mentioned above. These viruses are all transmitted by aphids in a stylet-borne, nonpersistent manner. They can be both acquired and transmitted in as few as 15 seconds. They are all transmitted by a large number of aphid species (Kennedy & Eastop 1962), all of which are abundant throughout California (Summers, unpublished data, Pike et al. 1992). Due to the rapidity with which the viruses can be acquired and transmitted, insecticides are of little value in preventing virus spread and under some circumstances, may actually increase the rate of virus transmission and spread (Broadbent 1994, Gibson & Rice 1989). This has not, however, dissuaded a large number of growers and PCA's from attempting to control the spread of these viruses with the use of insecticides. In a trial conducted at the Kearney Agricultural Center in 1995, tomato plots receiving five application of Admire had the same incidence of virus infection (approximately 50%) as plots receiving no insecticides (Summers & Stapleton, unpublished data).

Reflective mulches have been used successfully to reduce the incidence of aphid-borne virus diseased in squash and other crops (Brown et al. 1993, Chalfant et al. 1977, Conway et al. 1989, Moore et al 1965, Summers et al. 1995, Stapleton et al. Stapleton et al. Stapleton & Summers 1994, Summers & Stapleton 1995). Brown et al. (1993) found silver plastic mulch superior to white, yellow or black with yellow edges in repelling aphids in yellow crookneck summer squash. Plants grown on reflective mulch produced significantly higher yields of marketable fruit than did those grown on bare soil . Other materials and colors used to successfully reduce virus incidence in various crops include: aluminum foil (Dickson & Laird 1989, Harpaz 1982, Johnson et al. 1967, Kring 1969, More et al. 1965, Nawrocka et al 1975, Wyman et al 1979), white plastic (Harpaz 1982, Wyman et al. 1979), aluminum powder sprayed on the soil (Harpaz 1982) and aluminum strips painted on black plastic (Lamont et al. 1990). Summers et al. (1995) found that silver spray mulch and two silver polyethylene film mulches, applied to the planting beds before seeding, were effective in repelling alate aphids and delaying the onset of several virus diseases in spring and fall-planted zucchini squash in California's San Joaquin Valley. Disease symptoms in plants growing over these mulches appeared 7-10 days later than in plants growing on unmulched beds. In spring seeded squash, approximately 30% of the plants on unmulched beds were infected with one or more viruses by the first harvest while only 10-15% of those grown over the silver mulches showed virus symptoms. In fall-planted trials, 100% of the plants grown on unmulched beds, with and without insecticide applications, were virus-infected by the first harvest. Less than 10% of plants grown over silver mulches were diseased at first harvest. Marketable fruit yields in the spring planting were approximately 70% higher in plots mulched with silver than the unmulched control. In the fall trial, yields of marketable fruit were 75 and 80% greater in plots mulched with silver polyester film and silver spray respectively, than those from the unmulched control, either with or without an insecticide application. Although plants the unmulched controls. Stapleton & Summers (1994) also showed that cantaloupe grown over reflective mulches yielded over 500 cartons of marketable fruit per acre compared to less than 50 cartons per acre from plants grown on bare soil. An earlier and higher rate of infection with CMV in plants grown over bare soil was the only difference between the plots. Reflective mulches delayed the onset of virus infection by four to six weeks thus allowing the plants time to mature and set a good crop of melon fruit before becoming infected.

More recently a great deal of interest has developed in the area of conservation tillage and the use of cover crops into which vegetable are either seeded or transplanted. The theory behind the use of cover crops is that tillage is reduced, the cover crops adds tilth and structure to the soil and helps open compacted soils, the cover prevents the germination and growth of weeds, legumes such as vetch add nitrogen to the soil and the decomposing crops itself adds long term nitrogen to the soil. Little, however, is known about the incidence of insects or diseases in crops grown under such circumstances.

Current Research

Materials and Methods. All trials, including grower cooperator studies, were arranged in a randomized complete block design. Depending of the particular study, the number of replications varied from four to six. Except for the reflective plastic mulches and the used of experimental insecticides, which formed the main variable in most experiments, all cultural practice were typical for vegetables grown in the San Joaquin Valley. **Tomatoes:** The tomato study evaluated three production methods for producing fresh market tomatoes 1) transplanting into reflective mulch, 2) transplanting into a cover crop that has been killed and chopped, and 3) a conventional planting into fallow beds. Two experiments were conducted, the first a spring planting (April) and summer (July) harvest and the second a summer planting (July) fall harvest (September). The spring cover crop, consisting of a mixture of rye, triticale, and vetch was planted in Oct. The summer cover crop was a sorghum/sudan hybrid and was planted in April. Both were allowed to grow until just prior to transplanting the tomatoes. They were then chopped with a stock chopper and killed with Roundup ®. Both the reflective mulch plots and the conventional plots received per-plant herbicide and fertilized according to commercial practices in the area. The cover crop plots received neither. Data collection included: a) weekly aphid counts both on the plants and in yellow pan water traps located in each plot. b) counts of Lepidoptera larvae including tomato fruit worm, beet armyworm, looper, and yellow striped armyworm. c) counts of stink bugs, stilt bugs, and "suck" bugs. d) leafminer evaluations. e) virus disease incidence. f) incidence of foliar and vascular diseases. At maturity, mature green fruit were harvested, weighed, and graded. We kept very detailed records of all labor, chemical, and other inputs into each of the three treatments. We will conduct a complete economic analysis of the three management systems during the winter of 2000.

Tomatoes--Alleopathy Studies: In the summer planting, we used a sorghum-sudan hybrid as the cover crop. This plant proved to be alleopathic to tomatoes. We further investigated the effect by planting the grass and then killing it as we had done in the tomato experiment. A portion of the plot was tilled into the soil and a portion left with the stubble and mulch of the surface. A third treatment consisted of fallow ground never seeded to the grass. Transplants of tomato, broccoli, and lettuce were planted into each plot. Six plants of each species were transplanted into each plot and each treatment (plant species) was replicated four times. A total of 24 plants of each species was thus transplanted into the experiment. One month later, these plants were harvested and dry weight obtained. We also obtained dry weight of weed biomass from a one square foot area in each plot.

Squash--multiple management strategy: We conducted a multiple management strategy experiment that incorporated the three aphid-virus-whitefly management strategies available to grower in order to determine which was the most effective. Replicated plots (5 reps in a RCBD) were established at KAC. The treatments evaluated included: 1) reflective mulch, 2) a virus resistant variety, 3) pre-plant Admire®. The Admire was shanked ca. 5-6 cm deep at 8 oz. per acre. Additional treatments included: 4) no mulch, 5) a virus susceptible variety, and 6) no pre-plant insecticide. Following seedling emergence, plots were sampled weekly for alate aphids, adult and nymphal silverleaf whiteflies, virus disease incidence and squash silverleaf symptoms. At maturity, plots were harvested every other day and fruit separated into marketable and unmarketable, the latter category consisted of virus injured fruit and fruit bleached by silverleaf whitefly injury. A complete economic analysis of the three management systems will be conducted during the winter of 2000. In addition, we held two field days and at each obtained grower input and evaluation of the three management strategies through a series of questionnaires filled out by the growers. Their responses are currently being analyzed. Additional squash plots evaluated several new reflective mulches. **Squash--New Plastics and Insecticides:** Several new plastics, including: 1) a less reflective material (Sonoco Dull, Exhibit 4) reported to be less expensive that the standard reflective (Sonoco Bright, Exhibit 3) mulch we have used in the past. 2) "net cut" (Exhibit 2) of a material shown in the past to be effective in repelling aphids and silverleaf whiteflies. 3) A reflective plastic mulch of a "holographic design" which reflects multiple colors (Exhibit 1) and an insecticide (Fulfill ®) reported by the developing chemical company as controlling aphid-borne viruses by paralyzing their feeding muscles, were evaluated. All experiments were arranged in A RCBD with four replications. **Squash--Biomass Accumulation:** Although we have observed that squash plants growing over reflective mulch grow more rapidly, accumulate more biomass, and produce fruit earlier than plants growing over bare soil, these facts have never been documented. We conducted an experiment with two treatments: 1) plants grown over reflective mulch, 2) plants grown over bare soil. Each plot consisted of a double row, 25 feet in length and replicated six times in a RCBD. Beginning one week after planting and continuing on a weekly basis until early fruit production, 10 plants from each plot were cut at ground level and then the roots carefully dug up and washed. Both foliage and roots were dried in a forces air drying oven and the dry weight obtained. As reproductive structures, i.e. flowers and fruit appeared, theses were also harvested, dried and weighed. All plants were selected at random with the exception that only disease free plants were sampled and weighed.

Pumpkin: A grower cooperator field trial was conducted in Tulare and Fresno counties on pumpkins. Ten acres in each of two field were mulched with reflective plastic mulch. Eight rows on each side of the field and eight in the center of the field were left unmulched as controls. Pumpkins were planted in July and August. One hundred plants in each of the mulched and unmulched were marked for data collection which consisted of aphid counts, virus evaluation, and yield determination. Each "plot" area was replicated 4 times throughout the field.

Eggplant: We evaluated two insecticides applied through the drip irrigation immediately after transplanting, reflective mulch, and fallow beds for the management of Heteroptera attacking eggplants. Treatments included: 1) Admire at 8 oz. per acre, 2) Platinum at 1.04 gm AI per 100 meters of row, 3) Platinum at 2.08 gm AI per 100 meters of row, 4) reflective mulch, 5) control--fallow beds. Insects counts and disease determination were made weekly beginning one week after transplanting. At maturity, plots were harvested weekly and fruit weights obtained.

Corn: We evaluated four treatments for control and management of corn stunt leafhopper: 1) reflective plastic mulch, 2) Platinum applied at 1.04 gm AI per 100 meter of row, 3) Capture applied as a foliar spray at 16 oz. per acre, and 4) control--fallow beds. Beginning two weeks after seedling emergence. plots were sampled weekly using a D-vac to determine the population density of corn stunt leafhopper. Plots were visually accessed weekly and the number of plants showing corn stunt symptoms recorded. At maturity, ears were harvested, counted, and weighted.

Results and Discussion: Due the huge volume of data collected on this project during the summer of 1999 and because the season lasted so long (field trials continued until mid-November) much of the data has not been analyzed and in come cased even summarized. Here we present those data which we feel most significantly demonstrates the results of our summers work.

Tomatoes: The reflective mulch repelled alate aphids as we have observed in other experiments (Fig. 1). Early in the season, significantly (P = 0.05) more alate were found on plants grown under conventional tillage but as the season progressed, the numbers found in the cover crop plots and the conventional plots were significantly higher than those found on plants grown over reflective mulches. Figure 1a shows the accumulation of plant bio-mass in plants grown in the three management systems. Early in the season, there was no difference in biomass accumulation but after five weeks (30 May) plants growing over the reflective mulch grew significantly more rapidly and accumulated biomass quicker. By the end of the season as harvest approached, plants growing over the reflective mulches had accumulated 2.5 X the biomass of plants growing under the other production systems (Fig. 1a). The larger, more robust plants growing over reflective mulch produced significantly higher yield (Fig. 2). As might be expected, more culls were harvested from plants growing over fallow beds (Fig. 3). Fruit from this treatment exhibited more rot and more insect injury that fruit from the other treatments. Figure 4 shows the biomass accumulation for the summer planted crop growing under the three management systems. Once again, plants growing over the reflective mulches accumulated significantly more biomass, and a an earlier stage of growth than did plants growing under the other production systems. Note particularly that there was almost no biomass accumulation in the cover crop plots. This was due to the fact the sorghum-sudan hybrid we chose as the cove crop turned out to be alleopathic to tomatoes when shredded as used as a cover crop. This will be discussed more thoroughly in the following section. Both the cover crop and the reflective mulch were effective in suppressing weed growth (Fig. 5). It no not certain, however, how much of the weed suppression in the cover crop plots was due to alleopathy (see following section) and how much was due to just the cover itself. Since this is only the first year of the project and much of the data are yet to be summarized and analyzed, it is not appropriate to draw too many conclusions. This study will be repeated during 2000 and the cover crop for the spring planted crop has already been planted. We will select a different cover crop (not sorghum-sudan hybrid) for the summer planting although the decision on which crop has not yet been made.

Tomatoes--Alleopathy Studies: Sorghum-sudan hybrid was selected as the summer cover crop because it is a warm season grass and because pervious experience with that species, when incorporated onto the plant beds, did not show any evidence of toxicity (Don May, personal communication). We first observed the impact of the sorghum-sudan on tomato transplants ca. 7-days after transplanting. The majority of plants had died and those remaining were severely stunted. Plant in the other two treatments had overcome transplant shock and were growing well. We continued to replant the tomatoes for up to four more weeks with the same results, the majority of plants dies and those that did survive were severely stunted. The dramatic failure with tomatoes planted into the sorghum-sudan cover crop lead us to hypothesize that the sorghum-sudan hybrid was alleopathic which lead us to establish an experiment to determine if this were true. Table 1 shows the number of plants surviving (out of the original 24 transplanted) and the dry weight per plant. All three species transplanted into plots that had been cut and the stubble killed with Roundup and left on the soil surface had a significant lower dry weight that did plants transplanted into fallow soil or into soil where the sorghum-sudan had been incorporated. Additional, fewer transplants survived in the stubble treatment. (See Photo 1). We did not observe the degree of plant death that we had observed in the original tomato experiment but, that study had been transplanted in July and in the present alleopathy study, the plants were transplanted in late September. Significant difference in daily soil and air temperatures could well have had an effect. There is no question however, that something in the sorghum-sudan hybrid is toxic to all three of the plants tested. The stubble plots also had a significant impact of weed growth (Table 2). We believe this substance to be a water soluble compound leached out of the straw by the drip irrigation water. Further laboratory and greenhouse tests are underway this winter to determine the exact nature of the toxic substance.

Squash--Multiple Management Strategies: At the present time, only three strategies are available for the management of aphid-borne viruses in fall planted cucurbits. These are 1) insecticides, 2) resistant cultivars, 3) reflective plastic mulch. Likewise, the management of silverleaf whitefly relies on either the use of insecticides, or the application of reflective plastic mulch. This experiment was designed to evaluate each of these strategies, alone and in combination, to determine the most economical way of managing these pests. The incidence of aphid-borne virus diseases was most reduced by the use of reflective mulch, followed by the use of resistant varieties, and finally, the application of a pre-plant insecticide (Admire) (Fig. 6). The incidence of squash silverleaf, an indicator or silverleaf whitefly infestation, was most impacted by reflective mulch. Plots planted over reflective mulch remained whitefly free for the longest period of time (Fig. 7). Yields, based on the total number of marketable fruit, (Fig. 8) support the above conclusion. Only reflective mulch produced a significantly higher yield. All other treatments were similar in yield. Plots planted over bare soil (Fig. 8) had the lowest yields of any of the treatments. The analysis of the economics of each strategy is still underway. These same plastics were evaluated for the effect of silverleaf whitefly as determined by the incidence of squash silverleaf. (See Photo 2).

Squash--New Plastics and Insecticides: The incidence and development of aphid-borne virus diseases was limited equally by the standard mulch ("Sonoco Bright"), the less reflective mulch ("Sonoco Dull") and the Specialty Ag mulch ("Bird-Ban Cut") (Fig. 9). The incidence of aphid-borne viruses in the plots treated with the insecticide Fulfill, did not differ from that in the untreated check, and during the early growth period, the incidence of virus infected plants was actually higher in the insecticide treated plots than in the untreated check (Fig. 9). This is similar to previously reported results (Broadbent 1994, Gibson & Rice 1989). The two solid mulches, (Sonoco Bright and Sonoco Dull), repelled silverleaf whitefly adults most effectively (Fig. 10). Plants grown over the solid mulches, (Sonoco Bright and Sonoco Dull), produced significantly higher yields that did plants grown over the other mulches, the control, or plants treated with Fulfill (Fig. 11). The holographic mulches were similar to the standard mulch in reducing the incidence of aphid-borne viruses diseases (Fig. 12) and the incidence of squash silverleaf (Fig. 13). Yields form plants grown over all three mulches were significantly higher that from plants grown over bare soil (Fig. 14).

Squash--Biomass Accumulation: Plants growing over reflective mulch clearly accumulated more biomass at a more rapid rate and earlier than did plants growing over bare soil (Fig. 17). Similar results were found with root mass accumulation (Fig. 16) and the accumulation of reproductive tissue (Fig. 15). Since only disease free plants were sampled, the differences in biomass accumulation of foliage, roots, and reproductive structures was due strictly to the environment in which they were grown i.e.. over reflective mulch or over bare soil.

Pumpkins: Two grower cooperator plots of pumpkins, 10 acres each using reflective mulch and fallow beds, were evaluated. Figure 18 shows that yields from plants growing over reflective mulch were 2 to 5 times higher than from plants growing over fallow beds. Studies such as these support the notion at reflective mulches not only work in small experimental plots but also work under larger commercial production.

Eggplant: A new, unidentified malady appears to be affecting eggplant in the San Joaquin Valley. (See Photo 3). At this point, the malady remains unidentified. We are working to establish its identity, causal agent, and vector, if any. We evaluated reflective mulch and two insecticides applied immediately after transplanting. Fig 19 shows that only the reflective mulch was effective in reducing (in this case eliminating) this malady. Yields were also significantly higher from plants growing over reflective mulch (Table 3).

Corn: The incidence of corn stunt disease was significantly reduced in plants growing over reflective mulch. Neither a per-plant insecticide treatment or a post-emergence foliar treatment reduced the incidence of this disease (Fig. 20). Yields were also higher in plants growing over reflective mulch. This study is the third in three years in which the incidence of corn stunt disease has been significantly reduced in plants growing over reflective mulches. This confirm that reflective mulches repel the leafhopper vector of this disease. This is the first definitive work showing that reflective mulches repel leafhoppers (Summers and Stapleton, 1998; Stapleton and Summers 1998; Summers and Stapleton, 1999).

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Glossary of Terms, Abbreviations, and Symbols:

A1y=mulch/insecticide/susceptible variety. A2x=mulch/no insecticide/resistant variety. A2y=mulch/no insecticide/susceptible variety. B1x=no mulch, insecticide/resistant variety. B1y=no mulch/ insecticide/susceptible variety. B2x=no mulch/no insecticide/resistant variety. B2y=no mulch/no insecticide/susceptible variety.

RCBD = Randomized Complete Block Design

Appendix I--Tables

Table 1. Dry weight of tomatoes, lettuce, and broccoli transplanted into different treatments of sorghum-sudan grass hybrid.

Treatment	No. plants surviving			Mean weight (g) per plant		
	Tomato	Lettuce	Broccoli	Tomato	Lettuce	Broccoli
Stubble	18	1	20	0.24	0.33	0.93
Incorporated	21	16	24	1.03	4.11	4.77
Fallow	24	18	24	0.99	3.40	3.24

Table 2. Influence of sorghum-sudan grass hybrid as stubble, incorporated, or fallow soil on winter weed germination, growth, and biomass accumulation.

Treatment	Weed Biomass [1] Accumulation; g/ft. [2]
Stubble	1.52 a [2]
Incorporated	12.07 b
Fallow	13.34 b

1 Dry weight. Weeds were not separated by species but were comprised of both broadleaves and grasses, mainly redmaids, and annual blue grass.

2 Means follow by the same letter(s) are not significantly different at P = 0.05. Fishers LSD.

Table 3. Mean eggplant yields (season totals, pounds per plot) from plants grown over reflective mulch, treated with insecticide and grown over bare soil with on mulch or insecticide.

Treatments	Yield/Plot--Marketable	Yield/Plot--Unmarketable
Reflective Mulch	391	59
Platinum [1]	233	47
Admire [2]	292	45
Control [3]	113	38

1 Applied via drip immediately following transplanting. 1.04 g AI./100 m.

2 Applied via drip immediately following transplanting. 8 oz. per acre.

3 No mulch or insecticide.

Table 4. Corn yields from plants grown over reflective plastic mulch, treated with selected insecticides, or bare soil.

Treatment	Mean Wt. of		Total No. Ears
	Unhusk Ears [1]	Husk Ears [2]	
Reflective Mulch	15.53	0.46	155
Platinum [3]	14.49	0.35	162
Capture [4]	12.62	0.36	141
Control [5]	11.36	0.31	154

[1] Mean weight in pounds per plot.
[2] Mean weight per ear in pounds
[3] Applied at 1.04 g AI. per 100 m.
[4] Applied at 015 pounds per acre foliar spray.
[5] Bare soil. No mulch and no insecticides applied.

Appendix II--Figures

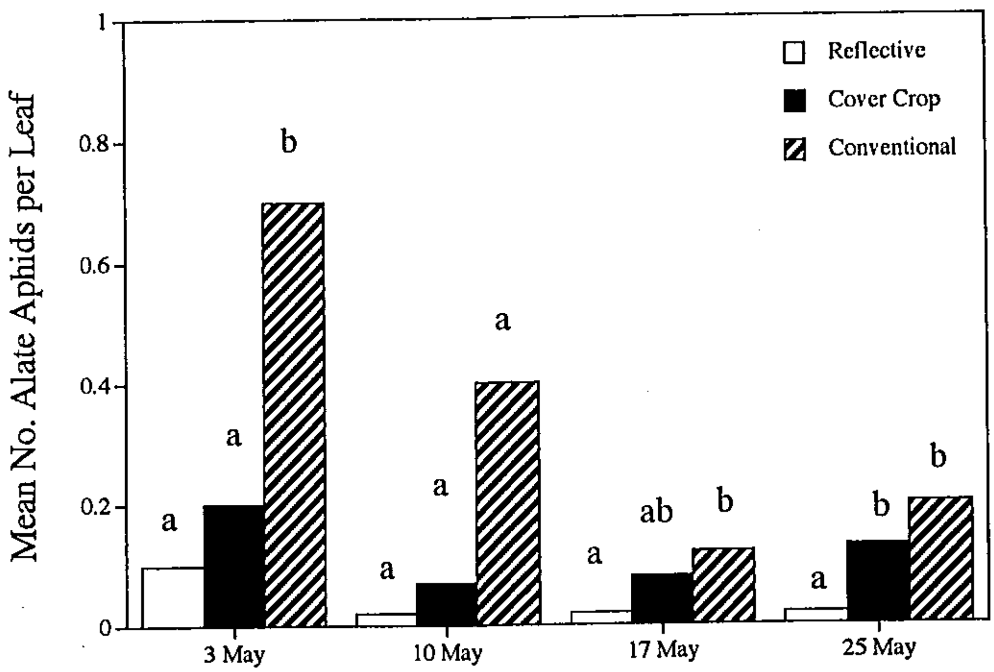

Figure 1. Development of alate aphid populations on tomatoes grown under three management strategies. Bars containing the same letter(s) are not significantly different at P = 0.05.

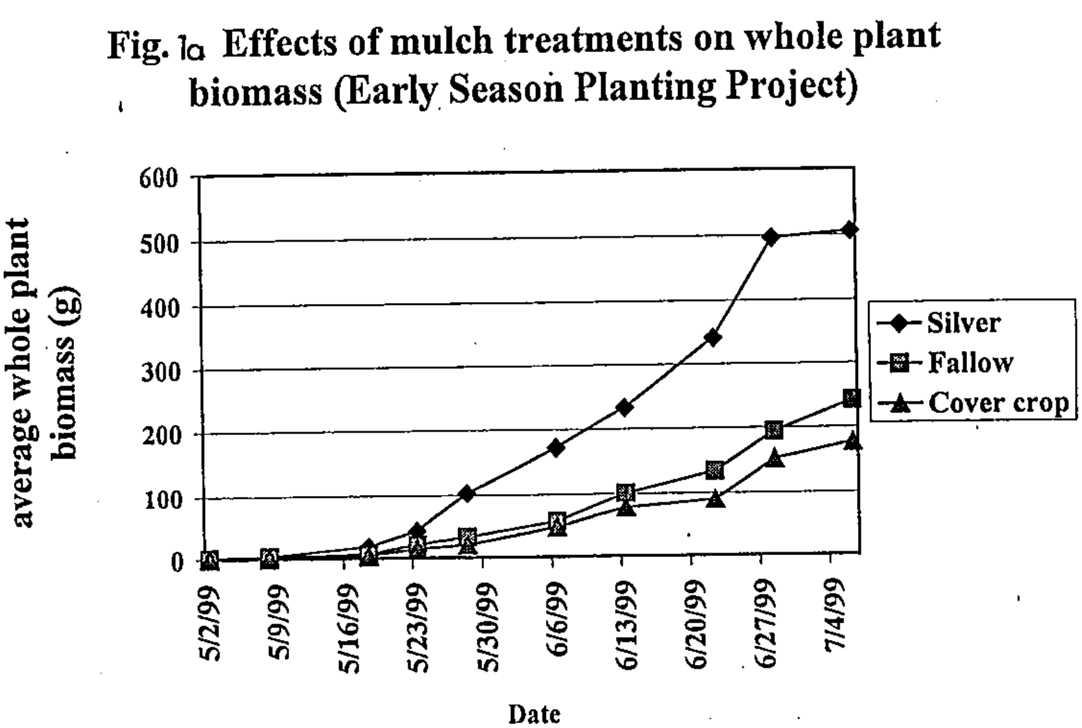

Figure 1a. Effect of mulch treatment on whole plant (tomatoes) biomass. Spring planting, 1999.

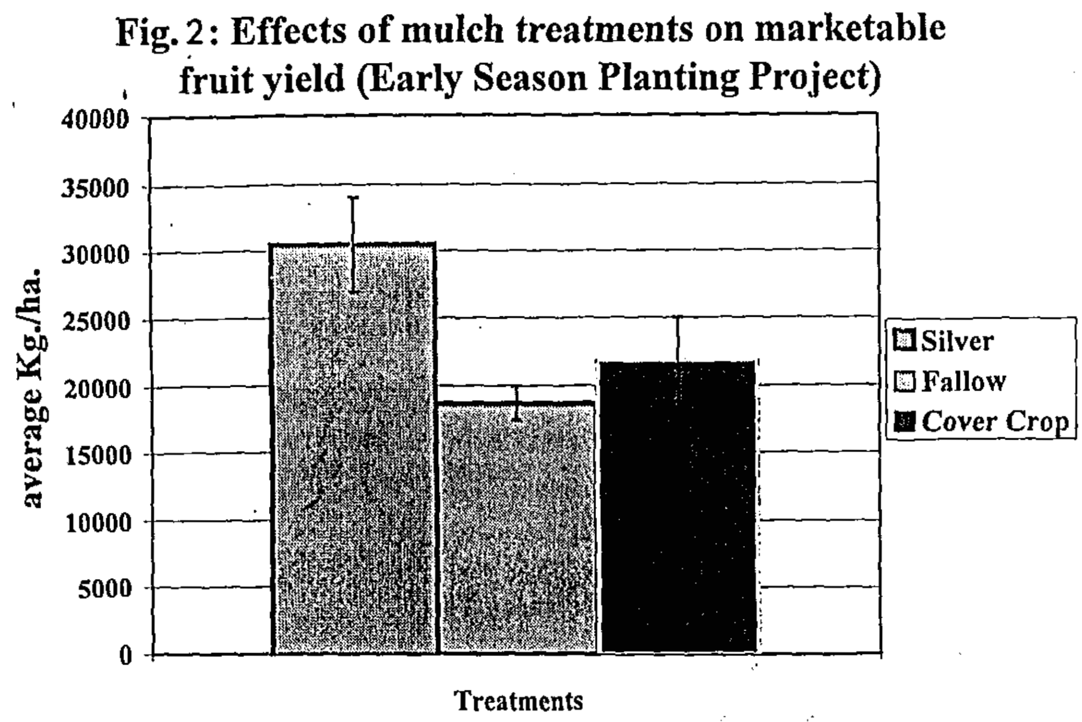

Figure 2. Effect of mulch treatment on tomato fruit yields. Spring planting, 1999.

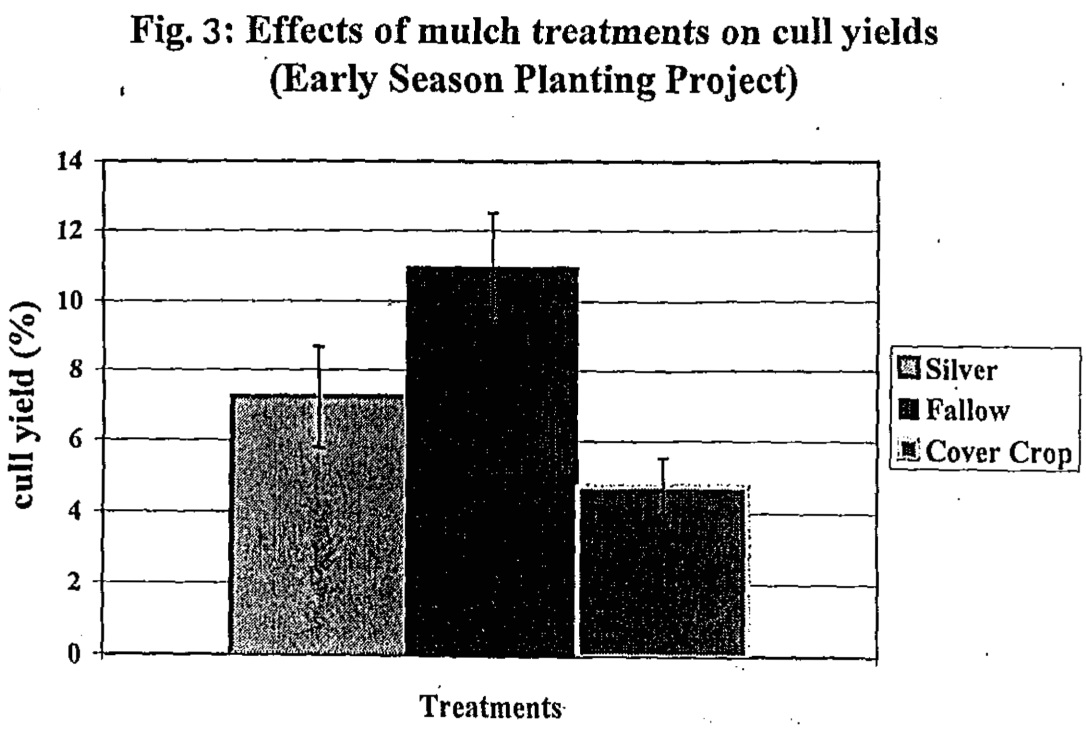

Figure 3. Effect of mulch treatment on yield of cull fruit (tomatoes). Spring planting, 1999.

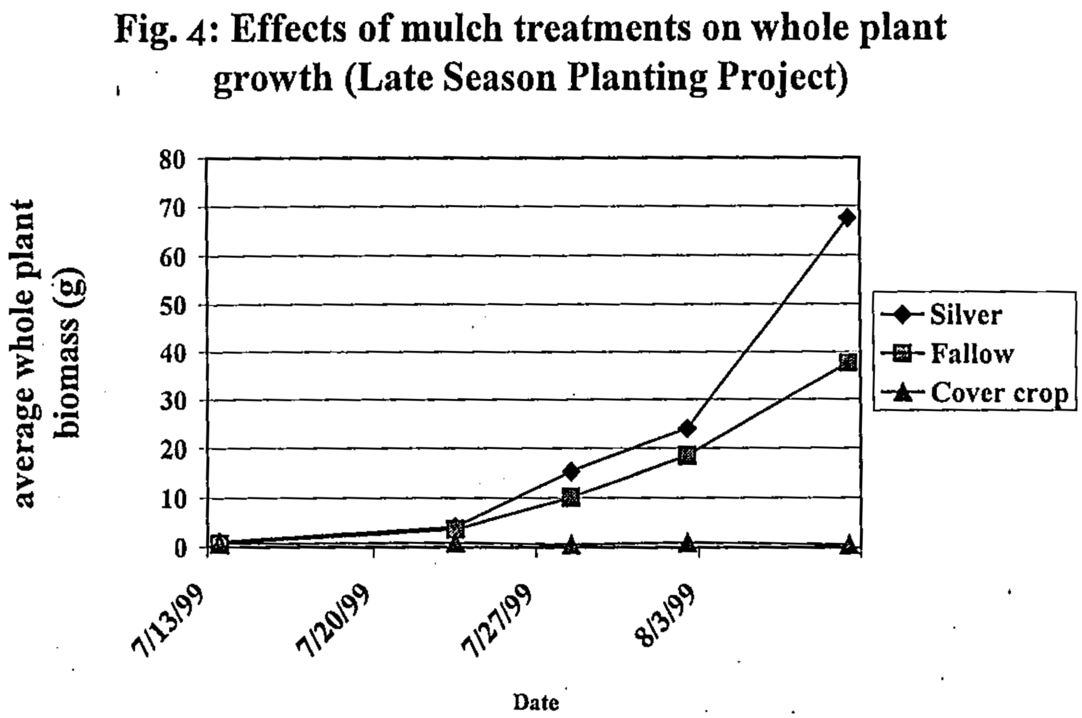

Figure 4. Effect of mulch treatment on whole plant (tomatoes) biomass. Summer planting. 1999.

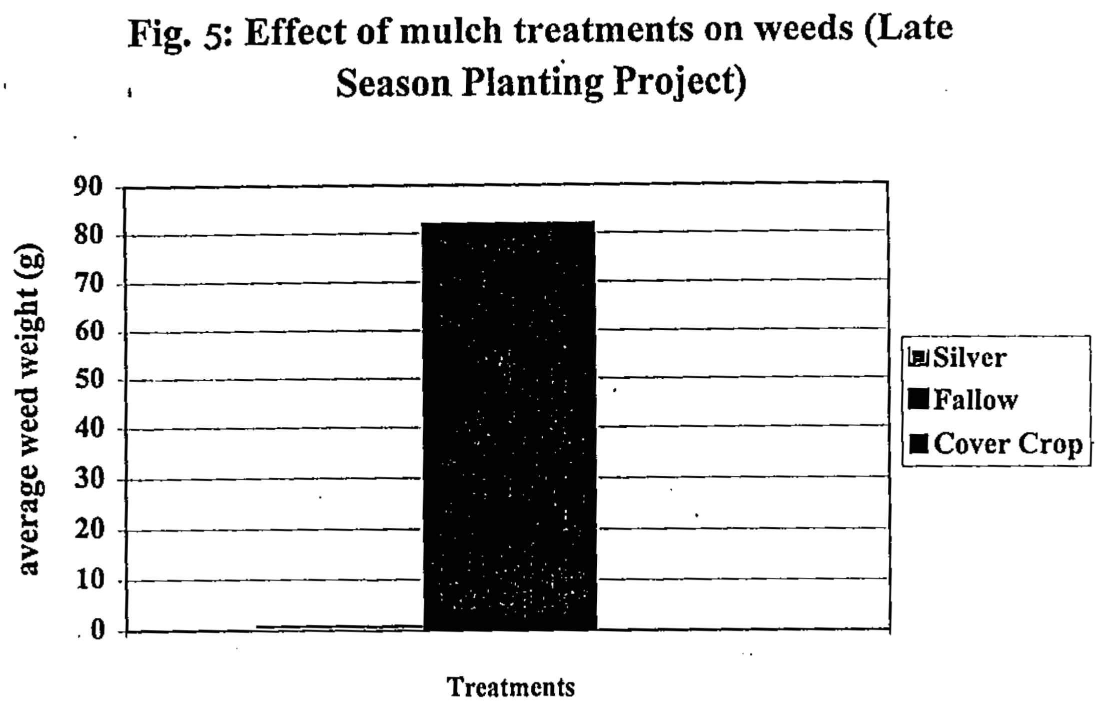

Figure 5. Effect of mulch treatment of weed emergence in tomatoes. Summer planting. 1999.

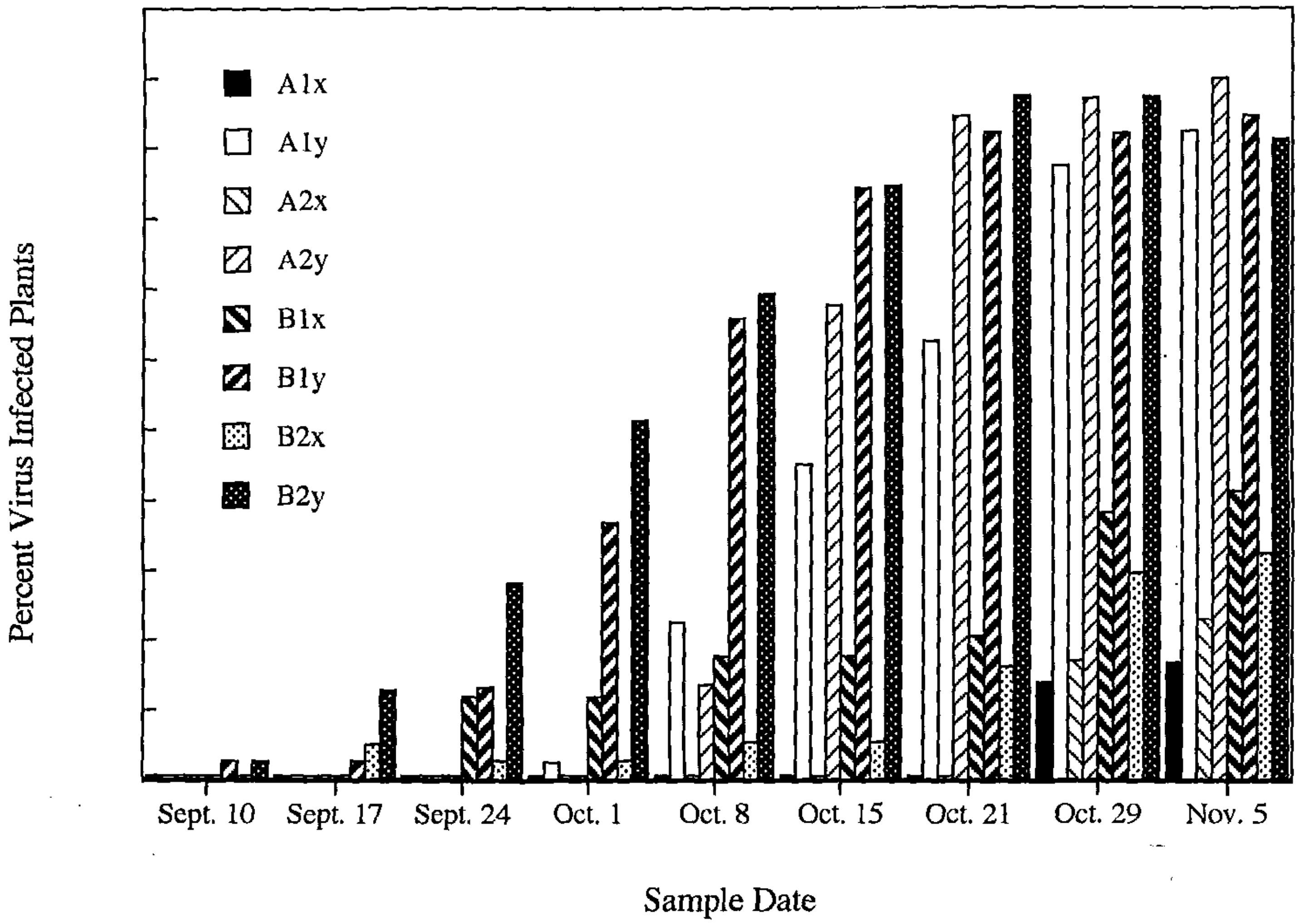

Figure 6. Percent of virus infected squash plants in multiple management experiment using reflective mulch, pre-plant insecticide, and resistant varieties. A1x=mulch/insecticide/resistant variety. A1y=mulch/insecticide/susceptible variety. A2x=mulch/no insecticide/resistant variety. A2y=mulch/no insecticide/susceptible variety. B1x=no mulch, insecticide/resistant variety. B1y=no mulch/ insecticide/susceptible variety. B2x=no mulch/no insecticide/resistant variety. B2y=no mulch/no insecticide/susceptible variety.

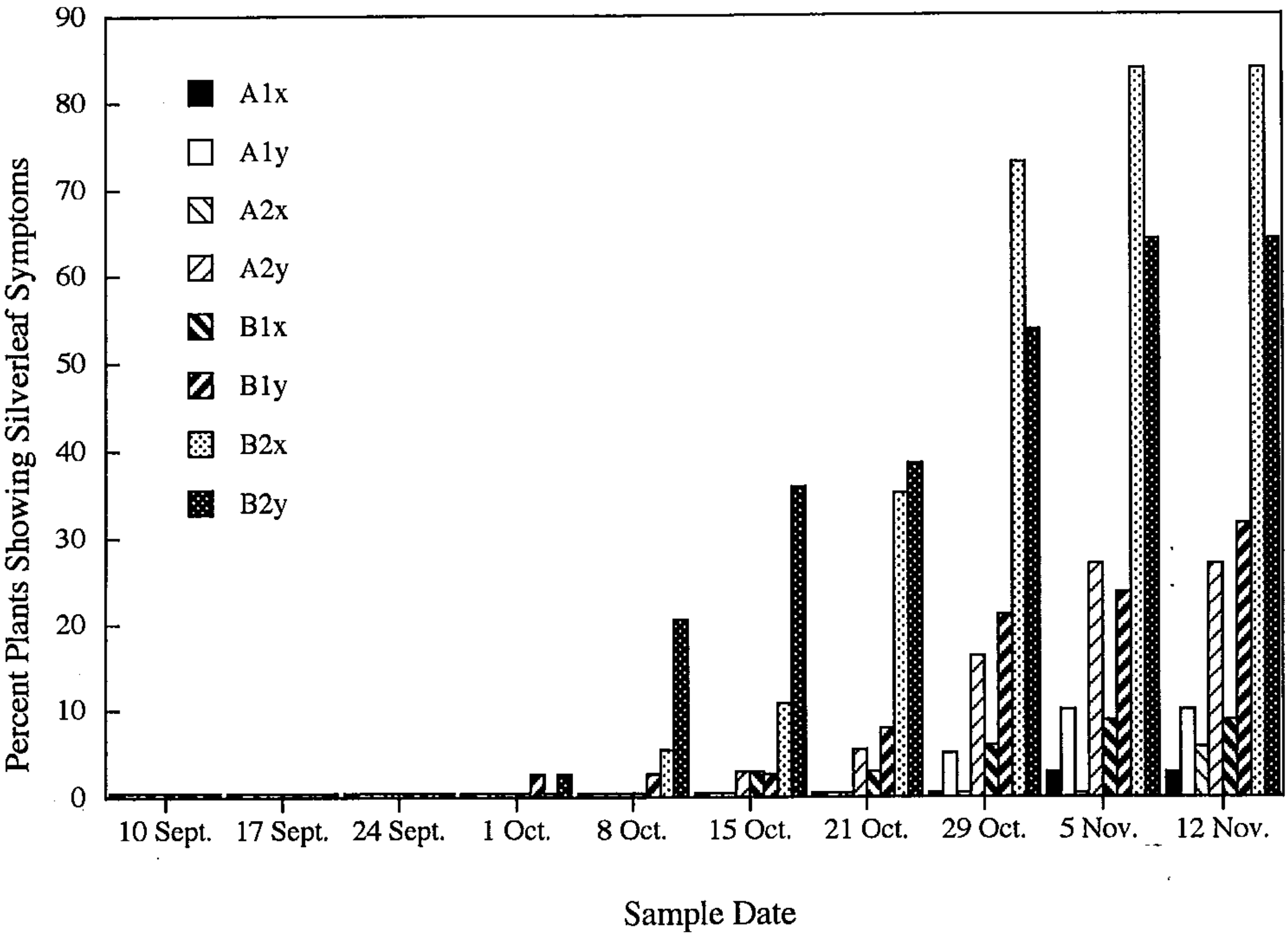

Figure 7. Percent of squash plants showing silverleaf symptoms in multiple management experiment using reflective mulch, pre-plant insecticide, and resistant varieties. A1x=mulch/insecticide/resistant variety. A1y=mulch/insecticide/susceptible variety. A2x=mulch/no insecticide/resistant variety. A2y=mulch/no insecticide/susceptible variety. B1x=no mulch, insecticide/resistant variety. B1y=no mulch/ insecticide/susceptible variety. B2x=no mulch/no insecticide/resistant variety. B2y=no mulch/no insecticide/susceptible variety.

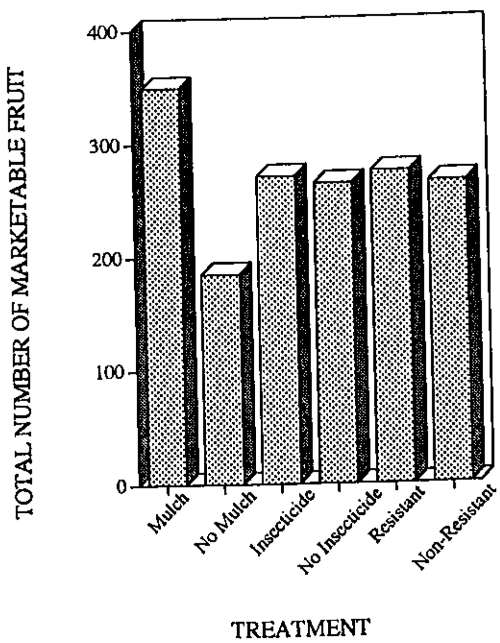

Figure 8. Total number of marketable squash fruit from multiple management experiment using reflective mulch, pre-plant insecticide, and resistant varieties.

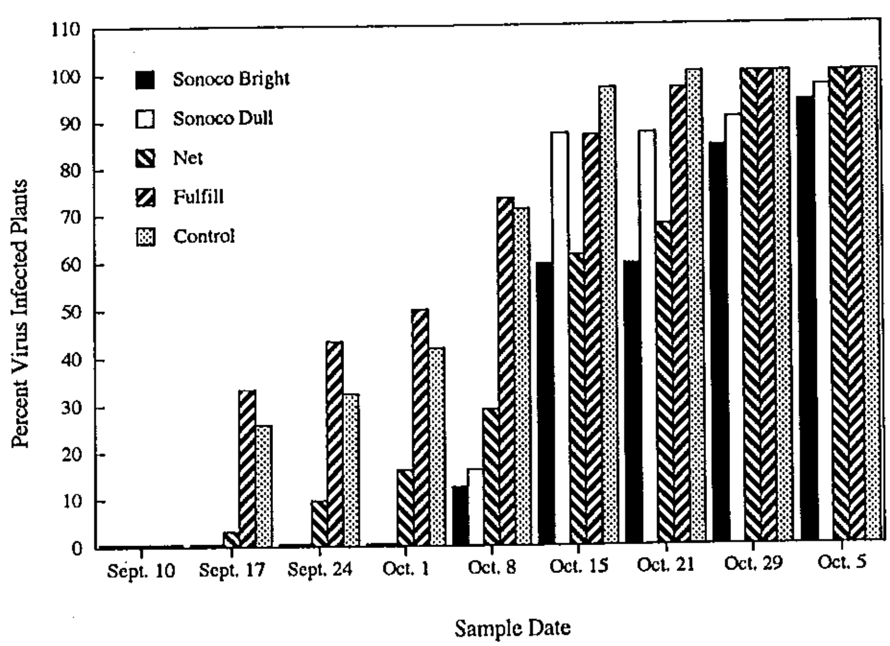

Figure 9. Percent virus infected plants from experiment using different reflective mulches and insecticides.

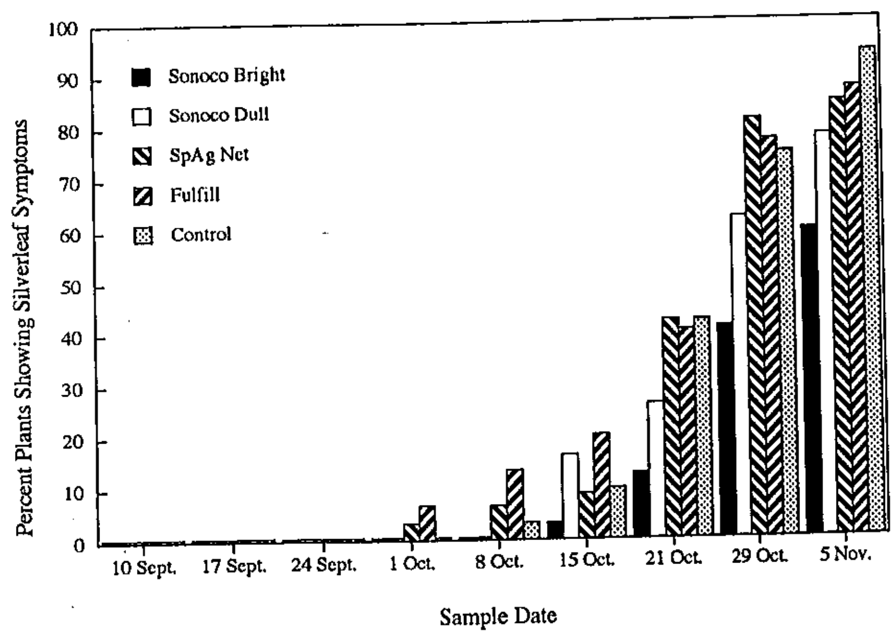

Figure 10. Percent plants showing silverleaf symptoms from experiment using different reflective mulches and insecticides.

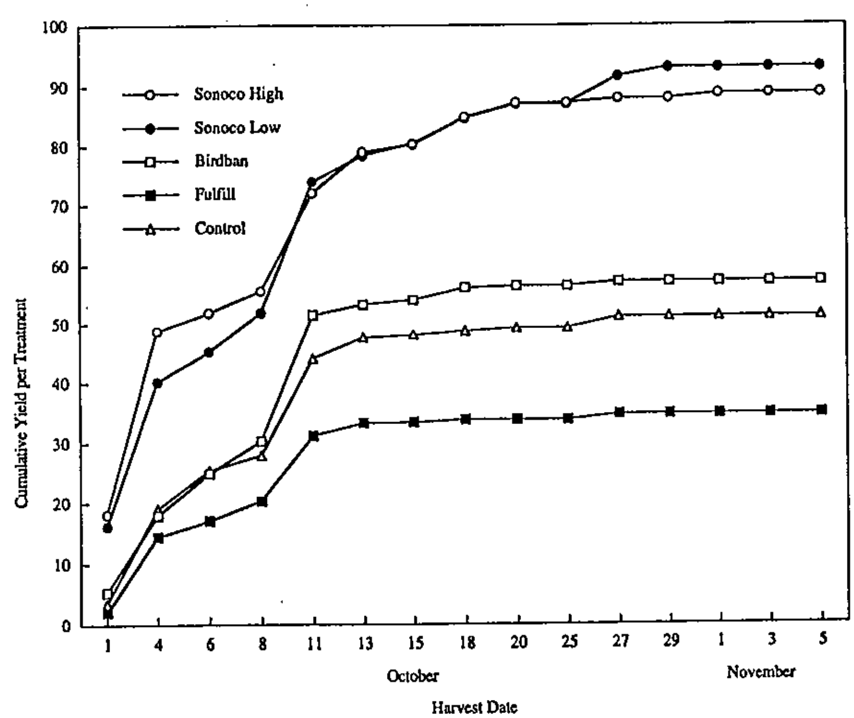

Figure 11. Marketable fruit yields from experiment using different reflective mulches and insecticides.

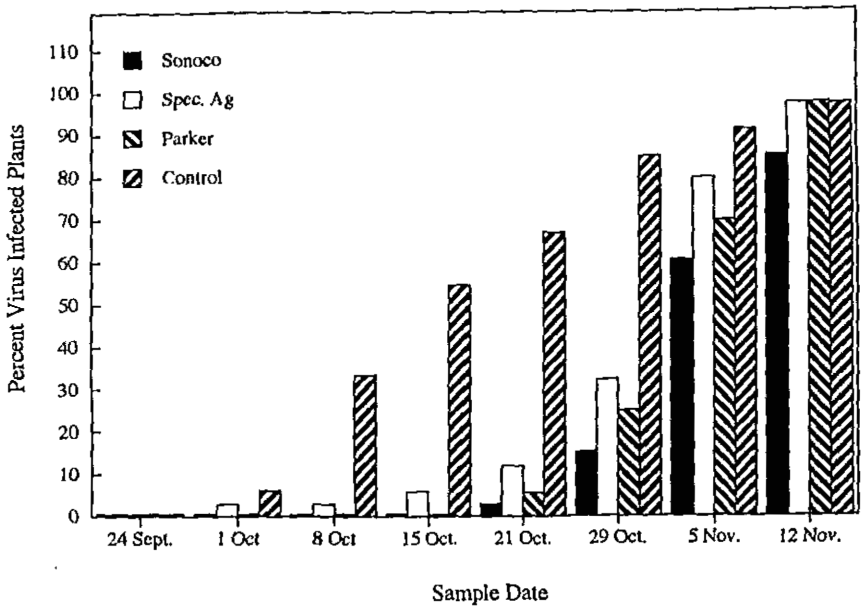

Figure 12. Percent virus infected plants from experiment using holographic reflective mulch.

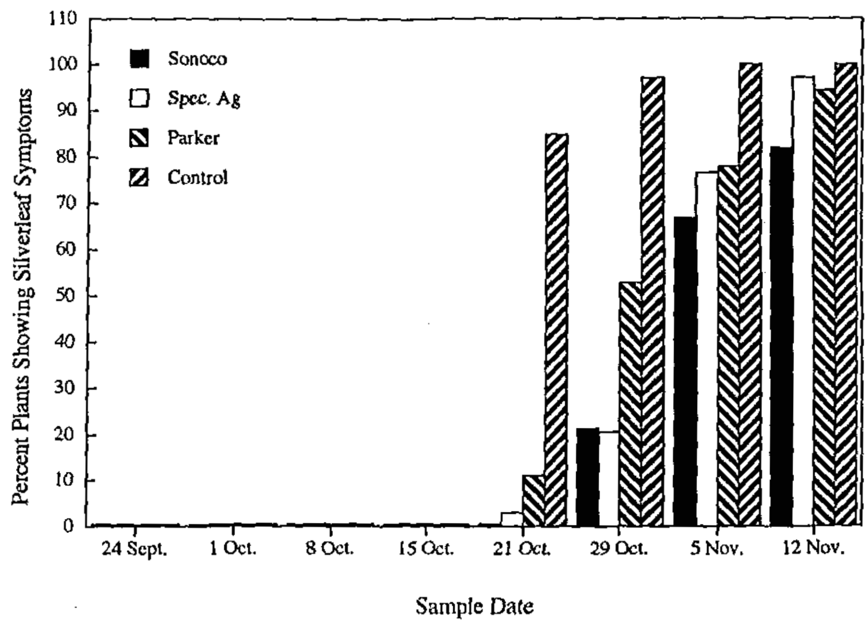

Figure 13. Percent plants showing silverleaf symptoms from experiment using holographic reflective mulch.

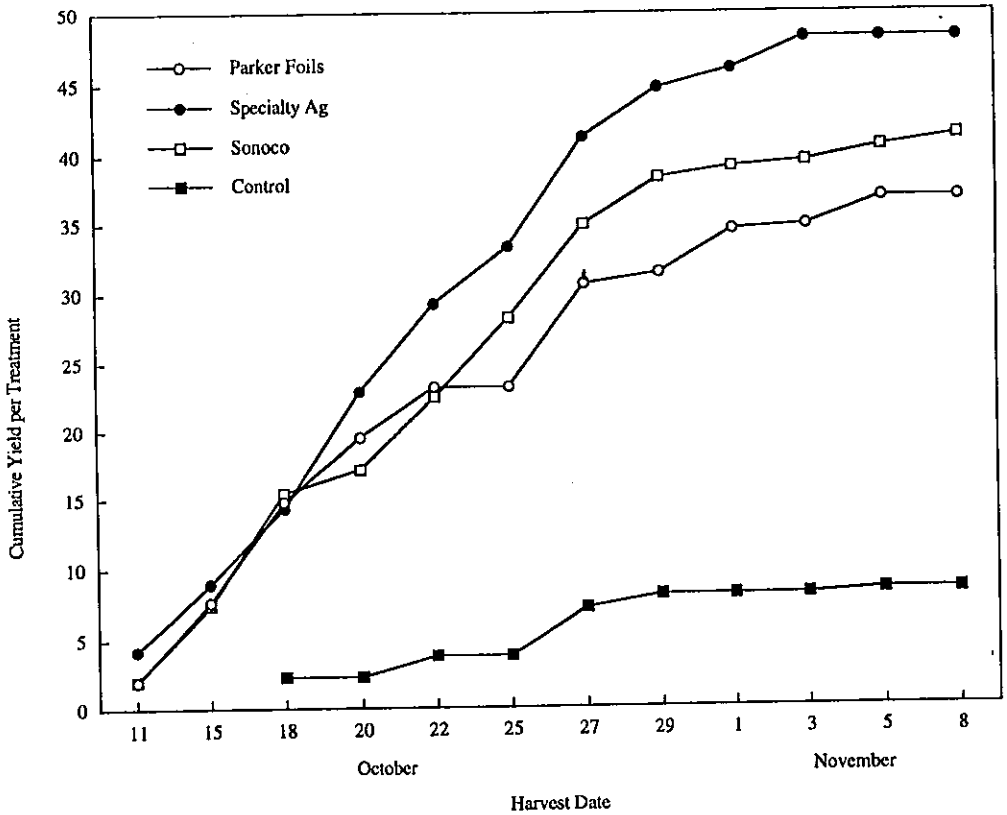

Figure 14. Marketable fruit yields from experiment using different holographic reflective mulches.

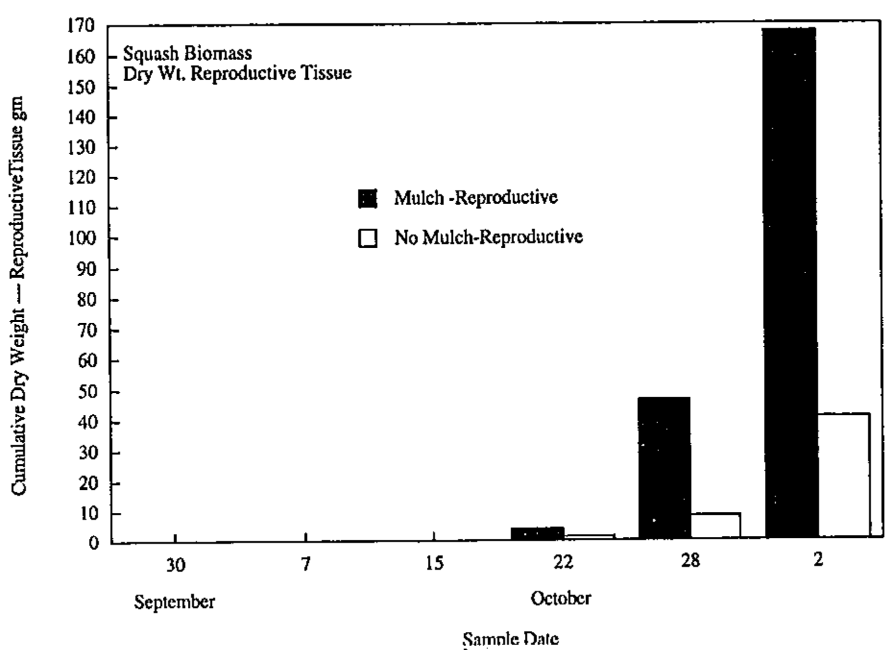

Figure 15. Dry weight of reproductive squash tissue from plants grown over reflective mulch and bare soil.

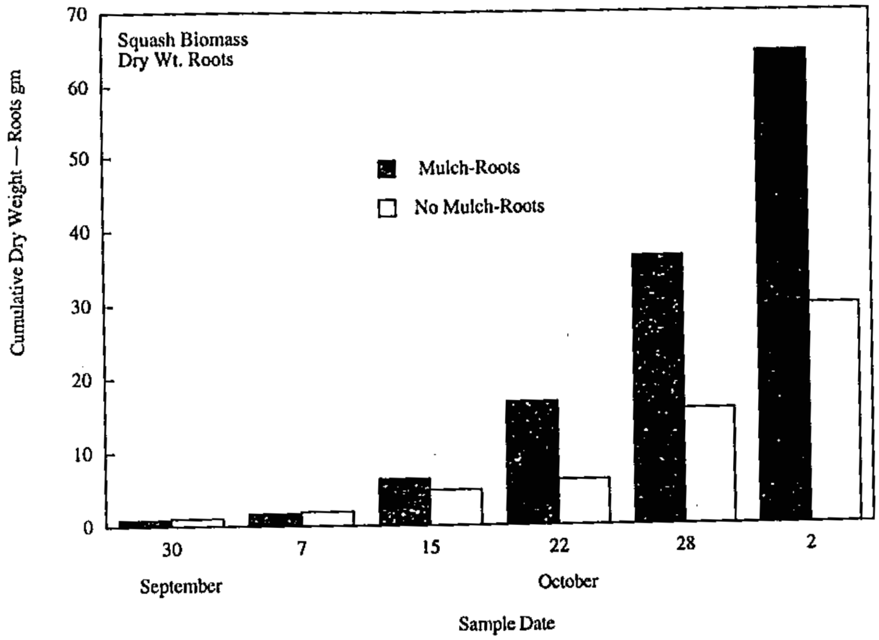

Figure 16. Dry weight of squash root tissue from plants grown over reflective mulch and bare soil.

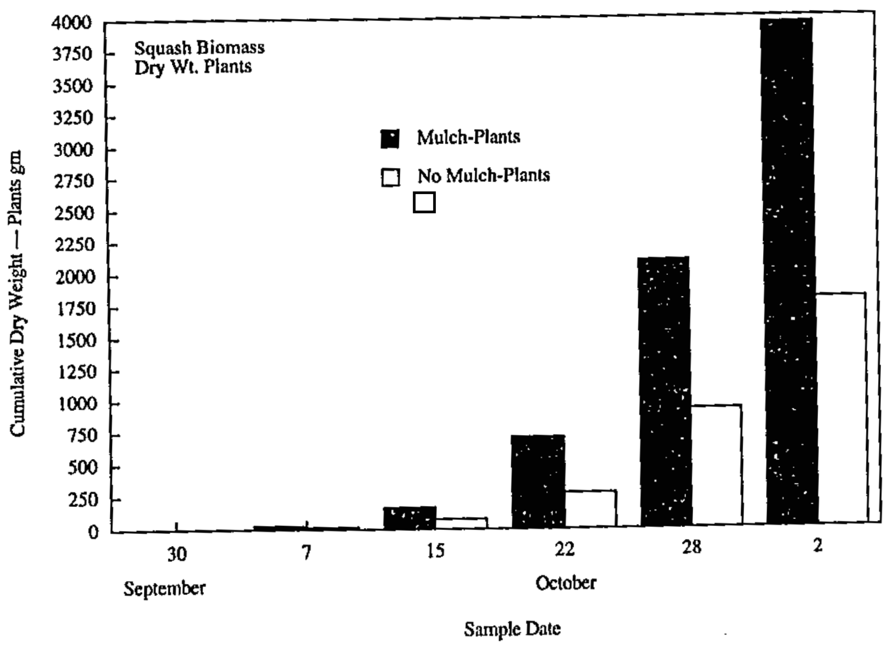

Figure 17. Dry weight of squash foliage tissue from plants grown over reflective mulch and bare soil.

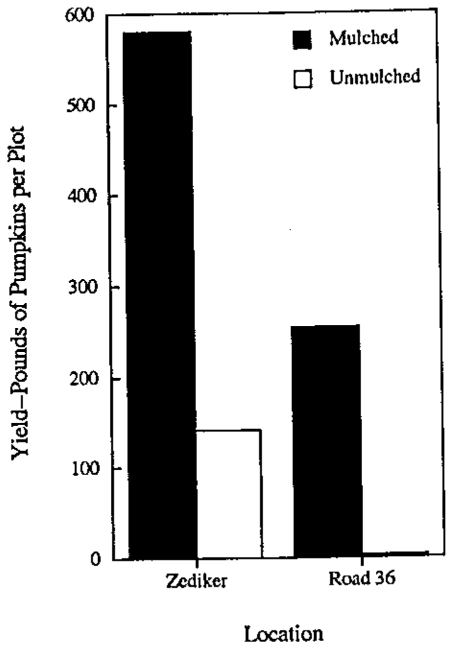

Figure 18. Pumpkin yields (pounds per plot) from two grower cooperator fields in Tulare and Fresno counties California. 1999.

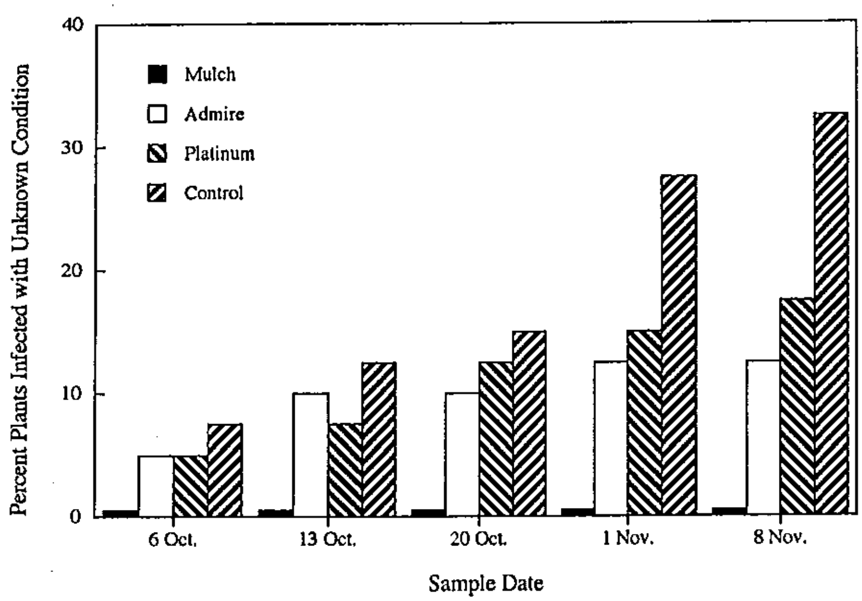

Figure 19. Percent of eggplant plants infected with an unknown condition thought to be a new virus disease. Plants growing over reflective mulch, insecticide treated, and growing over bare soil.

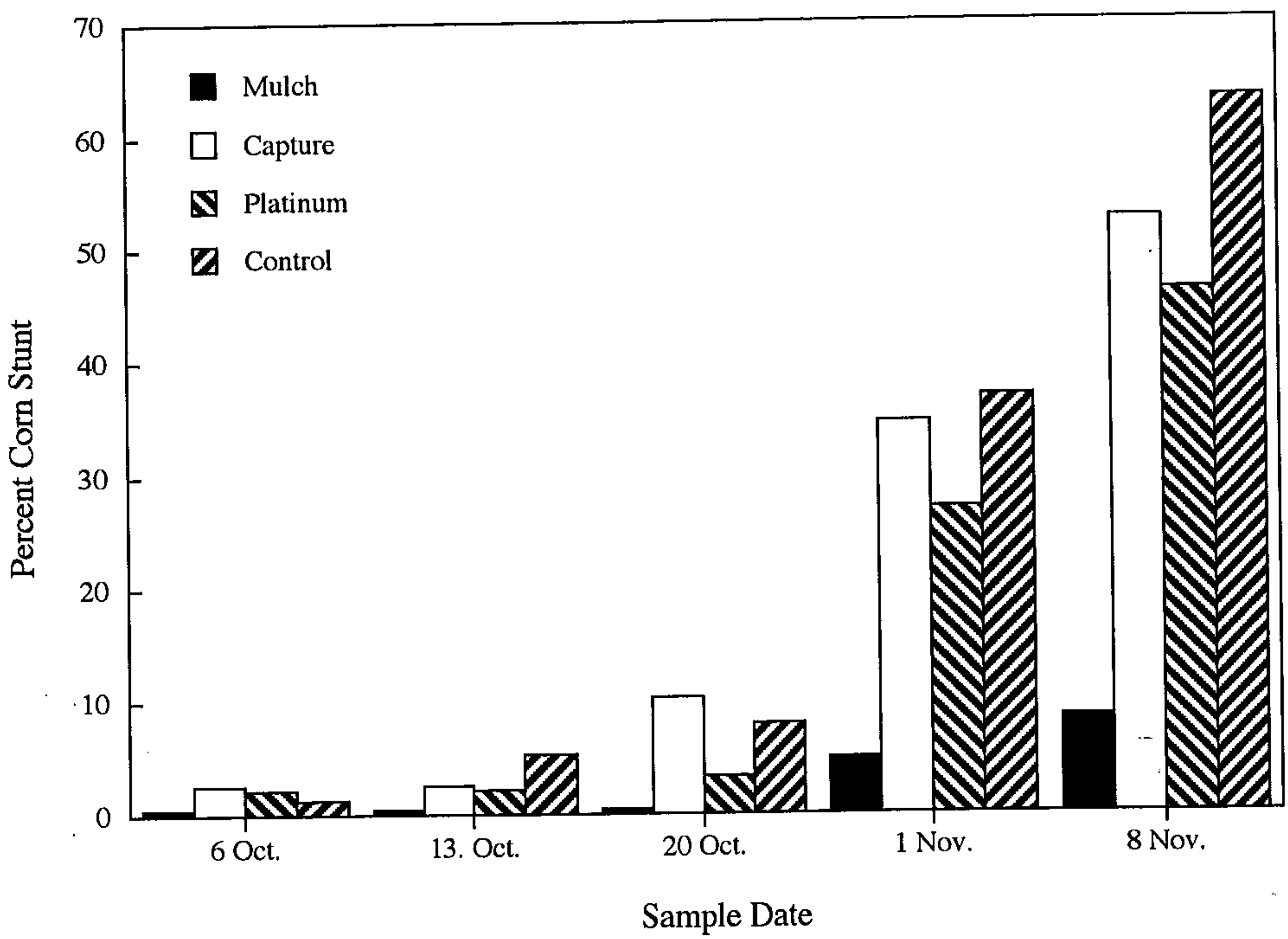

Figure 20. Percent of corn plants growing over reflective mulch, treated with selected insecticides, and bare soil, infected with corn stunt disease.