Non-Chemical Insect and Disease Management in Cucurbit Production Systems

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Abstract

We conducted experiments in 2000 and 2001 in California's San Joaquin Valley to evaluate the effectiveness of wheat straw and UV reflective plastic mulches for the management of silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring, and several aphid-borne virus diseases of zucchini squash. The effectiveness of these mulches was compared to a pre-plant application of imidacloprid (Admire®) insecticide and an unmulched, untreated control. Symptoms of both squash silverleaf, induced by nymphal whitefly feeding, and virus infection were significantly delayed and reduced by the baled wheat straw that was scattered over the beds and the UV reflective plastic. Wheat straw mulch obtained by planting winter (December) wheat, threshing the grain (June) and cutting the stubble (August) prior to squash planting discolored between harvest and squash planting and did not provide the high degree of reflectivity observed in straw that has been cut immediately after harvest, baled and then scattered prior to planting. Pre-plant Admire insecticide was not as effective in managing either whiteflies or the virus diseases as were the mulches. Yield of marketable fruit was significantly (P < 0.05) higher in 2000 from plants growing over the scattered wheat straw and the UV reflective plastic mulches than from those growing in the Admire treated or the control plots. In 2001 plants growing over the scattered wheat straw produced yields significantly (P < 0.05) greater than those from all other treatments. These data indicate that acceptable squash yields can be obtained without using chemical insecticides.

INTRODUCTION

Zucchini squash (*Cucurbita pepo* L.) is susceptible to several aphid-borne viruses, including cucumber mosaic (CMV), zucchini yellow mosaic (ZYMV) and watermelon mosaic (WMV). All are transmitted in a non-persistent manner by aphids. Plants may become infected with one or all of the viruses during their development. Plants infected by multiple viruses generally suffer more damage than those infected with only one virus. Insecticides offer little relief, as the viruses are acquired and transmitted within a short time, usually before the aphid vector obtains a lethal insecticide dose (Gibson and Rice, 1989). Some insecticides may actually enhance virus spread (Ferro et al., 1980). Silverleaf whitefly *(Bemisia argentifolii* Bellows & Perring) is also a serious pest of zucchini squash. Whitefly management using chemicals has not been effective (Denholm et al., 1996; Horowitz and Ishaaya, 1996) and there are few examples of effective biological control in vegetables (Heinz, 1996; Hoelmer, 1996). Silverleaf whitefly rapidly develops resistance to all classes of insecticides (Denholm et al., 1996; Prabhaker et al., 1998; Elbert and Nauen, 2000).

UV reflective plastic mulches have been used successfully to delay and reduce the incidence of aphid-borne virus diseases in squash and other crops (Summers and Stapleton, 1999; Summers and Stapleton, 1998; Brown, et al.; 1993) and to delay colonization by silverleaf whitefly and reduce the incidence of squash silverleaf (Edelstein et al., 1991; Summers and Stapleton, 2002). These mulches reflect short-wave UV light (Harpaz, 1982; Loebenstein and Raccah, 1980) which confuses and repels incoming alate aphids and adult whiteflies thus reducing their incidence of alighting on plants (Kring, 1972; Summers and Stapleton, 2002). Rummel et al. (1995) found that reflective wheat straw mulch retarded aphid development on cotton. Bwye et al. (1999) found a decrease in the incidence of cucumber mosaic virus in narrow-leafed lupine in plants grown over straw and Jones (1999) observed reduction in the incidence of bean yellow mosaic virus in lupines planted in cereal straw. Liewehr and Cranshaw (1991) determined that straw mulch decreased the incidence of alate aphid landings. The objective of this study was to determine if aphid-borne viruses and silverleaf whitefly could be managed without insecticides by using UV reflective plastic or wheat straw as mulches over which the squash crop developed.

MATERIALS AND METHODS

Planting beds were formed with a tractor drawn bed shaper with a distance between beds of 76 cm. Plots were 3 beds (2000) or 5 beds (2001) wide x 7.6 m long. Each plot was separated from adjacent plots by 4.6 m of bare soil on all sides. Dry fertilizer, (15-15-15 NPK) at 560 kg ha $^{-1}$ and bensulide (Prefar) herbicide at 5.6 kg (AI) ha $^{-1}$ in 189 liters of water ha $^{-1}$, was applied and incorporated to a depth of 15 cm with a second pass of the bed shaper. After seedling emergence, additional N (liquid 17-0-0), at 26 kg ha $^{-1}$, was applied through the drip system as needed.

Treatments were arranged in a randomized complete block design with six replications. Treatments in 2000 consisted of UV plastic mulch, scattered wheat straw, soil injected pre-plant imidacloprid (Admire®) and an untreated control. In 2001 winter planted wheat was added as a fifth treatment. The polyethylene mulches were applied by stretching the plastic over the planting beds and securing the edges with soil. In 2000, wheat straw, cv. Bonus, was scattered over one set of beds at the rate of 11,200 kg ha $^{-1}$. In the 2001 'Bonus' wheat, at 123 kg ha $^{-1}$, was drilled in one set of beds on 13 December 2000. The grain was harvested with a combine on 21 June 2001. One week before the squash planting (23 August), the straw stubble was cut with a sickle-bar mower. An additional set of plots had 'Bonus' wheat straw scattered over the beds as in 2000. Plots seeded to wheat or receiving scattered straw did not receive any pre-plant fertilizer or herbicide. Liquid fertilizer (17-0-0), at a rate equivalent to the pre-plant application, was applied to these plots through the drip system following seedling emergence. Admire insecticide, at 0.28 kg (AI) ha $^{-1}$) in 185 liters H_2O ha $^{-1}$, was injected into the soil 1-d before planting in both years. Planting holes were cut in the center of each plastic mulch strip. Spacing between plants in all treatments was 45 cm. Three seeds (cv. Ambassador) were planted per hill on 28 and 30 August 2000 and 2001, respectively. Following seedling emergence, plants were thinned to one per hill.

The incidence of plants with virus and silverleaf symptoms was determined weekly by visual inspection. At maturity, fruit was picked from the center row of each plot every other day, scored as marketable or unmarketable, weighed and yields recorded. The unmarketable category included fruit with virus symptoms and those bleached by whitefly feeding.

The percentage of plants presenting virus and silverleaf symptoms and yields were evaluated by analysis of variance and the means separated by Fishers Protected LSD (Abacus Concepts, 1989). The percentage of plants presenting virus or silverleaf symptoms was transformed to arcsine √ before analysis and back transformed for presentation.

RESULTS

2000 Trials

Silverleaf symptoms, induced by the feeding of silverleaf whitefly nymphs, first appeared on 25 September, approximately three weeks after seedling emergence. The incidence of squash silverleaf through 9 October was significantly ($P < 0.05$) lower in plants growing over the UV reflective mulch, the wheat straw and in plots receiving a pre-plant injection of Admire (Fig. 1A). The UV reflective plastic, and Admire had failed by 16 October but the straw mulch provided protection equal to that of Admire throughout the sampling period (Fig. 1A).

The UV reflective plastic mulch and the straw mulch each provided equal protection against aphid transmitted viruses (Fig. 1B). By 9 October, six weeks after planting, the incidence of virus infected plants growing over these two mulches was < than 25%. On the same sample date, the incidence of virus infected plants in the Admire treated plots and the untreated (control) approached 75% and were not significantly different from each other ($P > 0.05$). The UV reflective plastic and the straw mulch delayed the appearance of virus infected plants for 3-4 weeks.

Plants growing over UV reflective mulch and straw mulch produced significantly ($P < 0.05$) higher yields than those growing over the Admire and the untreated control plots (Fig. 2). The combination of whitefly and virus pressure in the untreated control plots resulted in a nearly complete lack of marketable fruit.

2001 Trials

The appearance of squash silverleaf in 2001 was identical to that observed in 2000, with the first plants showing symptoms on 24 September. Although no symptoms were observed the previous week, by 24 September 50% of the plants in the control plots presented symptoms and one week later, 1 October, 100% of the plants expressed symptoms (Fig. 3A). Admire lost its effectiveness by 1 October when over 50% of the plants in treated plots presented silverleaf symptoms. While Admire was relatively effective in reducing the incidence of silverleaf in 2000, it was not as effective in 2001. The UV reflective mulch provided protection through 1 October, but one week later (8 October) nearly 100% of the plants growing over the plastic mulch presented symptoms. The scattered wheat straw (from baled straw) provided the longest protection. Substantial silverleaf symptoms were delayed until 15 October. The planted wheat straw (planted in December, harvested in June and the stubble cut one week prior to planting) failed to protect the squash plants from whitefly infestation, as determined by the incidence of silverleaf. Silverleaf symptoms in these plots reached 100% by 1 October and did not differ significantly ($P > 0.05$) from the control. The wheat straw scattered from previously baled straw provided the best protection from whitefly buildup. The incidence of silverleaf in these plots did not equal that occurring in the control plots until 22 October.

Virus incidence was much less in 2001 than in 2000 (Fig. 3B). There was a very low occurrence of virus diseases until mid-October. Both the UV reflective plastic mulch and the scattered wheat straw provided excellent protection from virus infection throughout the growing season (Fig. 3B). Straw from the planted wheat also provided some protection throughout most of the season. Admire failed to provide any realistic protection; the incidence of virus infection in these plots not differing significantly ($P > 0.05$) from that in the controls (Fig. 3B).

All mulch treatments and the Admire treatment produced significantly ($P < 0.05$) higher yields than did the control plots (Fig. 4). Plants growing over the scattered wheat straw mulch produced the highest yields ($P < 0.05$) of any of the treatments (Fig. 4). Yields from the UV reflective plastic treatment and the Admire treatment were comparable.

DISCUSSION

The 2000 and 2001 seasons differed dramatically in both whitefly and virus disease incidence. Whitefly populations were more severe in 2001 and virus incidence was more severe in 2000. Whitefly densities were so high in 2001 that they quickly overwhelmed all of the treatments. Previous studies had indicated that the UV reflective plastic would significantly reduce the incidence of squash silverleaf for 4-6 weeks (Summers and Stapleton, 2002; Summers and Stapleton, 1999; Summers and Stapleton, 1998). In 2001, however, this protection lasted only 1-2 weeks. The scattered wheat straw provided the most effective protection from both silverleaf whitefly, as determined by the incidence of squash silverleaf, and from aphid-borne viruses. Even under the heavy whitefly pressure of 2001, plots mulched with wheat straw remained relatively free of silverleaf for 3 weeks, and in 2000, these plots had a reduced incidence of silverleaf for up to 4 weeks. Although wheat (and rice) straw is effective in repelling aphids and thus reduces the incidence of aphid-borne viruses (Bwye et al. 1999; Jones, 1999; Liewehr and Cranshaw, 1991) this is the first evidence that wheat straw is also effective in repelling whiteflies.

The wheat straw mulch provided protection from aphid-borne viruses equal to that of the UV reflective plastic. Straw scattered from bales brought into the field was superior to straw from planted wheat in reducing the incidence of aphid-borne viruses. Straw from the planted wheat stood in the field for 2+ months between the time the grain was harvested and when the straw was cut and laid down for surface mulch prior to squash planting. During this time, the straw was discolored considerably and did not present the bright yellow appearance of the scattered straw that had been cut and baled immediately after grain harvest. It is likely that the reflectivity of the planted wheat straw was not as great as that of the baled straw. Reflectivity readings for both straw types plus the reflective plastic and bare soil were taken, but the data have not been analyzed.

Yields of marketable fruit reflected the degree of silverleaf whitefly and virus disease suppression. Highest yields were from plants growing over scattered straw mulch or UV reflective plastic. These same treatments delayed the appearance of silverleaf and virus infected plants for the longest period of time. Plants grown over the planted wheat straw and in plots, which received a pre-plant treatment of Admire, produced yields intermediate between the scattered straw and reflective mulch and the control. While Admire was relatively effective in reducing the incidence of squash silverleaf, it was ineffective in reducing the incidence of aphid-borne viruses (Fig. 1B). This resulted in a significant reduction in the yield of marketable fruit compared to the reflective mulch and the straw mulch.

CONCLUSIONS

Wheat straw mulch, which was fresh and not discolored, as well as UV reflective plastic mulch provided management of silverleaf whitefly and aphid-borne virus diseases superior to that provided by Admire. Zucchini squash was successfully grown with acceptable yields without insecticides despite heavy silverleaf whitefly populations and intense virus disease pressure.

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Literature Cited

Abacus Concepts, 1989. SuperANOVA. Accessible general linear modeling. Abacus Concepts, Berkeley, CA.

Brown, J.E., Dangler, J.M., Woods, F.M., Henshaw, M.C., Griffy, W.A. and West, M.W. 1993. Delay in mosaic virus onset and aphid vector reduction in summer squash grown on reflective mulches. HortScience 28:895-896.

Bwye, A.M., Jones, R.A.C. and Proudlove, W. 1999. Effects of different cultural practices on spread of cucumber mosaic virus in narrow-leafed lupins (*Lupinus angustifolius*).

Aust. J. Agri. Res. 50:985-996.
Denholm, I., Cahill, M., Byrne, F.J. and Devonshire, A.L. 1996. Progress with documenting and combating insecticide resistance in *Bemisia*. p.577-603. In: D. Gerling and R.T. Mayer (eds.), *Bemisia*: 1995 Taxonomy, Biology, Damage, Control and Management. Intercept, Andover, U.K.
Edelstein, M., Paris, S.H., Shir, R., Beibowitz, G., Nerson, H. and Burger, Y. 1991. Effects of reflective plastic mulch on fall-grown summer squash. Hassadeh 71:868-869.
Elbert, A. and Nauen, R. 2000. Resistance of *Bemisia tabaci* (Homoptera: Aleyrodidae) to insecticides in southern Spain with special reference to neonicotinoids. Pesticide Mgt. Sci. 56:60-64.
Ferro, D.N., Mackenzie, J.D. and Margolies, D.C. 1980. Effect of mineral oil and a systemic insecticide on field spread of aphid-borne maize dwarf mosaic virus in sweet corn. J. Econ. Entomol. 73:730-734.
Gibson, R.M. and Rice, A.D. 1989. Modifying aphid behaviour. p.209-224. In: A.K. Minks and P. Harrewijn (eds.), Aphids: their Biology, Natural Enemies and Control. Elsevier, Amsterdam.
Harpaz, I. 1982. Nonpesticidal control of vector-borne viruses. p.1-21. In: K.F. Harris and K. Maramorosch (eds.), Pathogens, Vectors and Plant Diseases: Approaches to Control. Academic Press, New York.
Heinz, K.M. 1996. Predators and parasitoids as biological control agents of *Bemisia* in greenhouses. p.435-449. In: D. Gerling and R.T. Mayer (eds.), *Bemisia*: 1995 Taxonomy, Biology, Damage, Control and Management. Intercept, Andover, U.K.
Hoelmer, K.A. 1996. Whitefly parasitoids: can they control field populations of *Bemisia*. p.451-476. In: D. Gerling and R.T. Mayer (eds.), *Bemisia*: 1995 Taxonomy, Biology, Damage, Control and Management. Intercept, Andover, U.K.
Horowitz, A.R. and Ishaaya, I. 1996. Chemical control *of Bemisia*, management and application. p.537-556. In: D. Gerling and R.T. Mayer (eds.), *Bemisia*: 1995 Taxonomy, Biology, Damage, Control and Management. Intercept, Andover, U.K.
Jones, R.A.C. 2002. Effect of mulching with cereal straw and row spacing on spread of bean yellow mosaic potyvirus into narrow-leafed lupins (*Lupinus angustifolius*). Ann. Appl. Biol. 124:45:58.
Kring, J.B. 1972. Flight behavior of aphids. Annu. Rev. of Entomology 17:461-492.
Liewehr, D.J. and Cranshaw, W.E. 1991. Alate aphid traps capture over different background colors and different background patterns. Southwestern Entomol. 16:13-18.
Loebenstein, G. and Raccah, B. 1980. Control of nonpersistently transmitted aphid-borne viruses. Phytoparasitica 8:221-235.
Prabhaker, N., Toscano, N.C. and Henneberry, T.J. 1998. Evaluation of insecticide rotations and mixtures as resistance management strategies for *Bemisia argentifolii* (Homoptera: Aleyrodidae). J. Econ. Entomol. 91:820-826.
Rummel, D.R., Arnold, M.D., Slosser, J.E., Neece, K.D. and Pinchak, W.E. 1995. Cultural factors influencing the abundance of *Aphis gossypii* Glover in Texas high plains cotton. Southwestern Entomol. 20:395-406.
Summers, C.G. and Stapleton, J.J. 1998. Management of vegetable insects using plastic mulch: 1997 season review. U.C. Plant Protection Quarterly 8(1&2):9-11.
Summers, C.G. and Stapleton, J.J. 1999. Management of aphids, silverleaf whiteflies, and corn stunt leafhoppers using reflective plastic mulch and insecticides: 1998 season review. U.C. Plant Protection Quarterly 9(1):2-7.
Summers, C.G. and Stapleton, J.J. 2002. Use of UV reflective mulch to delay the colonization and reduce the severity of *Bemisia argentifolii* (Homoptera: Aleyrodidae) infestations in cucurbits. Crop Prot. (In Press).

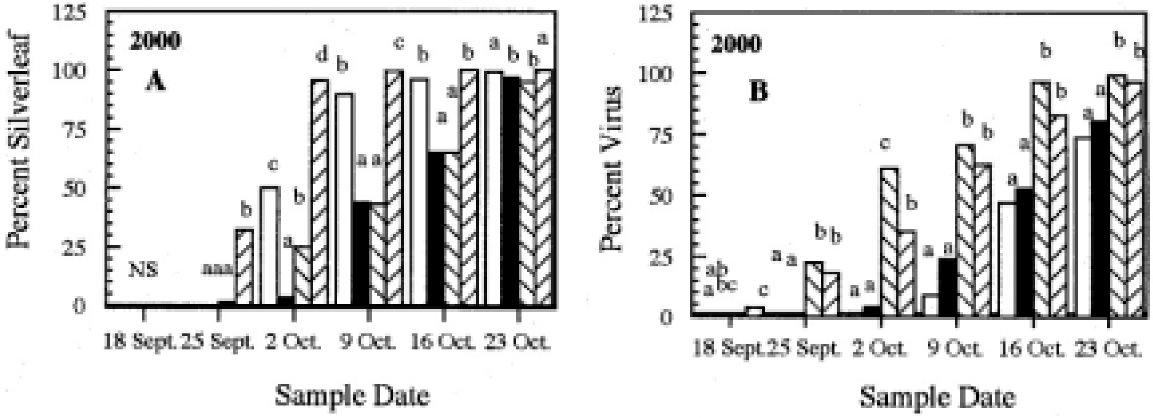

Fig. 1. Percentage of plants presenting silverleaf (A) and virus (B) symptoms. Means followed by the same letter or letters are not significantly different $P(= 0.05)$. Fishers protected LSD. □ Reflective ■ Straw ⧅ Admire ▨ Control NS = non-significant.

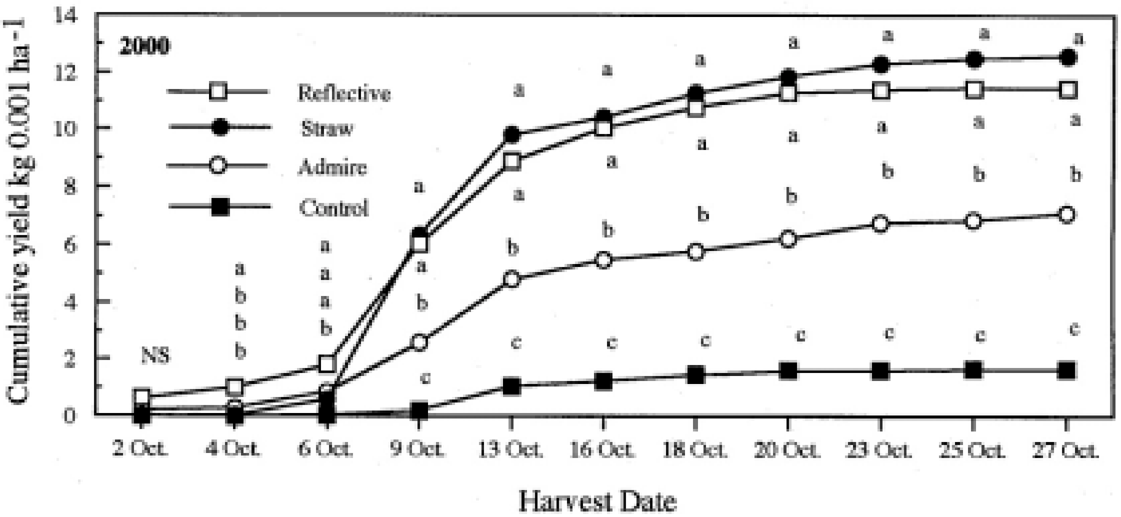

Fig. 2. Cumulative yield (kg 0.001ha $^{-1}$) of marketable squash fruit from four treatments. Mean followed by the same letter or letters are not signficantly different ($P = 0.05$). Fishers protected LSD. NS = non-significant.

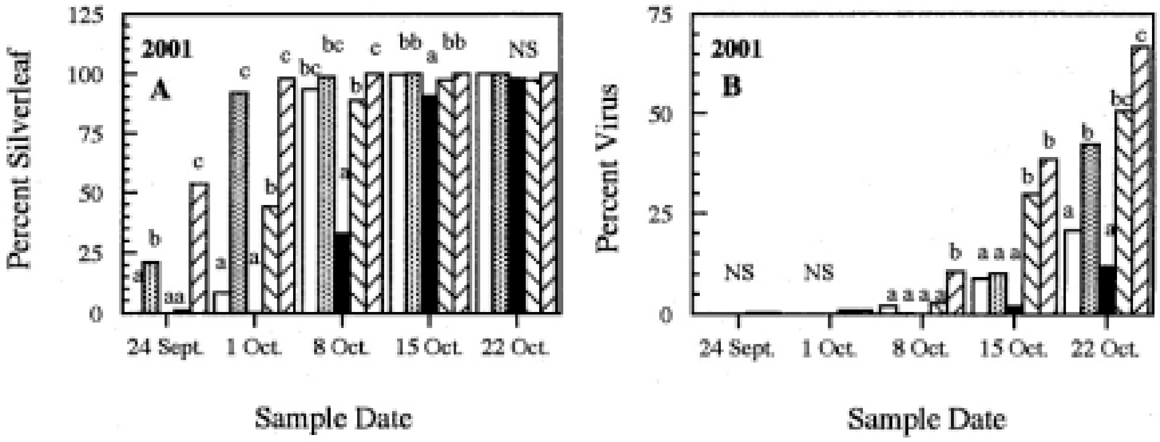

Fig. 3. Percentage of plants presenting silverleaf (A) and virus (B) symtoms. Means followed by the same letter or letters are not significantly different (P = 0.05). NS = non-significant. Silverleaf symptoms not observed before 24 Sept. and no virus symptoms were observed before 1 Oct. ☐ Reflective ▦ Planted Wheat ■ Scattered Straw ▧ Admire ▨ Control .

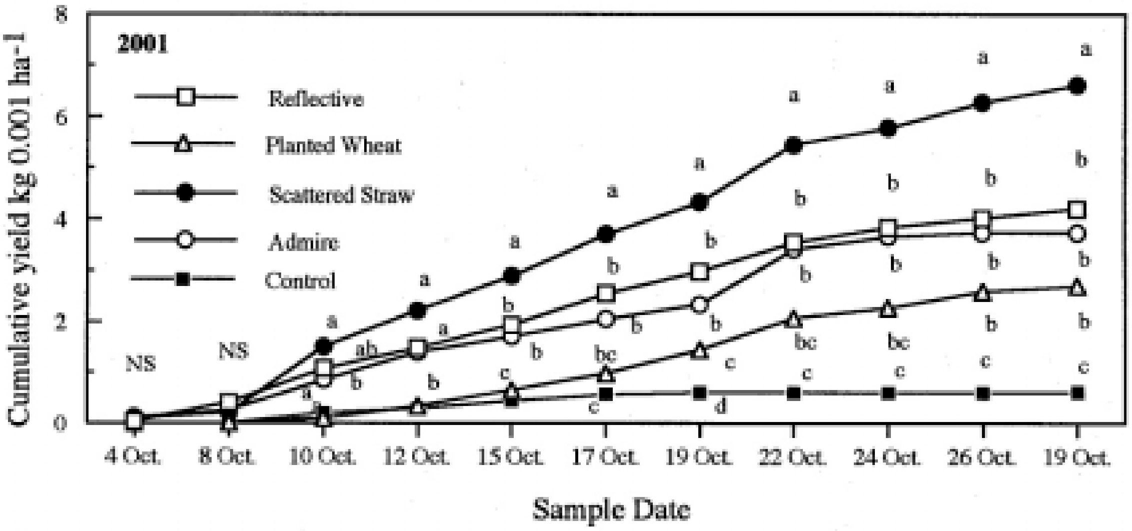

Fig. 4. Cumulative yield (kg 0.001ha $^{-1}$) of marketable fruit from five treatments. Means followed by the same letter or letters are not signficantly different (P = 0.05). Fishers protected LSD. NS = non-significant.