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Reflective Film Mulches, Millet Barriers, and Pesticides: Effects on Watermelon Mosaic Virus, Insects, Nematodes, Soil-borne Fungi, and Yield of Yellow Summer Squash[1]

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Abstract. **Field studies were conducted in 1973 and 1974 to determine the effects of various reflective film mulches, vegetal barriers of millet (*Pennisetum americanum* (L.) K. Schum), and soil- and foliar-applied pesticides on yields and control of the watermelon virus complex (WMV), insects, nematodes, and soil-borne pathogens affecting yellow summer squash (*Cucurbita pepo* var *melopepo* L. Alefi, 'Dixie'). All film mulches used (aluminum; white and blue plastic; brown paper) significantly reduced WMV in both fruits and plants. The millet barrier caused a significant reduction in WMV infected plants. In 1974, the systemic insecticide, carbofuran (Furadan) and/or sprays of mineral oil, significantly reduced WMV in non-mulched plots. Brown paper mulch significantly increased infestation of pickleworms, *Diaphania nitidalis* (Stoll) and all mulches significantly reduced infestations of serpentine leafminers, *Liriomyza munda* Frick. Leafminers were also controlled with carbofuran. Film mulches had no significant effect on populations of plant-parasitic nematodes and plant-pathogenic fungi. Both groups of pests were controlled with DD-MENCS (a mixture of 1,3-dichloropropene, 1,3-dichloropropane, methylisothiocyanate), but not with carbofuran or sodium azide. Film mulch increased squash yield 70 to 610% over the unmulched control. Plants in non-fumigated plots covered with aluminum and white plastic mulches produced significantly greater yields than plants in plots covered with blue plastic and brown paper mulches. Soil pesticides significantly increased yields over the non-fumigated control, and, averaged across main plots, DD-MENCS = DD-MENCS + carbofuran > carbofuran + sodium azide > sodium azide = nontreated check. The effects of film mulch were greatest in the non-fumigated check. Conversely, the effects of soil fumigation were negligible under film mulch and one could be substituted for the other.**

Yellow summer squash is a high-value crop widely grown in the southeastern U.S. Production is generally limited to the spring because several virus diseases are severe in late summer and fall. Soil-borne fungi and plant-parasitic nematodes are also severe during this time and may reduce yield.

Virus diseases of squash include tobacco ringspot virus, squash mosaic virus, cucumber mosaic virus and watermelon mosaic virus complex (WMV). Of these, WMV is the most common in Georgia (7).

Reflective film mulches have successfully reduced the spread of aphid-transmitted plant viruses in numerous crops. The surface of the film mulch reflects both short and long wave light and repels aphids from the mulched area (18). Several researchers (1, 10, 22, 25, 29) reported that aluminum film mulch reduced mosaic disease (mostly WMV), aphids, and other insect pests of squash. Use of aluminum film mulch has reduced turnip root aphids (4), sugarbeet yellows (11), pepper viruses (2), and thrips and cucumber mosaic on gladiolus (17, 24). Kring (18) concluded that failure of mulches to protect crops against virus diseases was caused by too little reflective surface, too many vectors, and growth of the crop over the reflective surface.

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Aphid-transmitted viruses have also been reduced by protective barriers planted around the crop to screen out viruliferous insects. Broadbent (3) concluded that vegetal barriers protected plants against nonpersistent viruses because immigrant aphids, feeding briefly on the barrier plants, lost the virus from their stylets. Barriers are most effective at wind velocities higher than 2.5 kph when aphids are less able to control settling behavior (18). In Georgia, Gay et al. (9) reduced cowpea mosaic on southern peas with barriers of disulfoton-treated millet. Either factor could have had a significant effect.

Insecticides generally have been ineffective in controlling nonpersistent insect-transmitted viruses such as WMV because they are usually transmitted before vectors are killed. Systemic insecticides, however, can reduce secondary virus spread within the field by preventing build up of vectors on primary virus sources (3, 12).

Mineral oil sprays have protected some crops against nonpersistent viruses (28). Laboratory studies (13) indicate that corn oil and mineral oil reduced the transmission of most nonpersistent viruses. The oil interferes with passage of the virus from aphid stylets to plant cells during feeding (8, 19, 27) and may adversely affect aphid larviposition (23) and retard symptom expression (6, 14). Cucumber mosaic virus and potato virus Y in pepper have been controlled with 2.5% mineral oil applied with an air-blast sprayer (21). Thorough coverage is essential and the oil is effective for 3–7 days. In another experiment, one application of oil protected lettuce against lettuce mosaic virus even after an elevenfold increase in leaf tissue (20).

Jaworski et al. (15) showed that film mulches in combination with DD-MENCS soil fumigation and drip irrigation doubled yields of squash compared with non-mulched controls. Yield increases were attributed to more favorable soil moisture and nutrition utilization and more effective control of soil-borne pathogens under film mulch. Research has not been reported that combines these production system features with a virus control program, utilizing the reflective value of film mulch.

This study investigated the possibility of producing high yields of disease- and insect-free summer squash by combining various production and disease control techniques consisting of reflective film mulch, drip irrigation, soil pesticides, foliar sprays and vegetal barriers.

Materials and Methods

Experiments were conducted in 1973 and 1974 on Tifton loamy sand (ca. 85% sand, 10% silt, 5% clay). Plots were raised beds 1.68 × 12.2 m. Experimental design was a randomized complete block, split-plot, with 4 replications. Main plots contained mulches or were surrounded by a 183-cm-wide barrier of millet (1974 only). Subplots were pesticide treatments.

The experimental field was made into beds. Solid fertilizer (81-69-129 kg/ha NPK in 1973, 131-48-134 kg/ha NPK in 1974) was broadcast and incorporated to a depth of 15 cm before planting. Supplemental fertilizer (129-22-41 kg/ha NPK in 11 applications in 1973, 161-19-36 kg/ha NPK in 25 applications in 1974) was added in the irrigation water. The entire field was then sprayed with the herbicide bensulfide 4EC (Prefar) at the rate of M.8 kg ai/ha and incorporated to a depth of 15 cm. Appropriate subplots received chemical treatments as follows: DD-MENCS (Vorlex) was injected at the rate of 929 liter ai/ha 25 cm deep into the soil with chisels 20 cm apart, and the soil surface was sealed by compaction with a bed-shaper attachment. Carbofuran 10% G (Furadan) or sodium azide (NaN_3) 8% G (Pittsburg Plate Glass Corp.) were broadcast at the rates of 22.2 kg ai/ha and 83.0 kg ai/ha, respectively, with a Gandy distributor then incorporated into the top 15 cm soil layer with a rototiller. The entire field was then sprayed with a second herbicide, amiben (Vegibin) 3.36 kg ai/ha). A single Viaflo drip irrigation tube (E.I. Du Pont de Nemours & Co., Wilmington, DE) was laid down the center of each bed. Appropriate main plots received either film mulch or were surrounded (1974 only) by three 61 cm wide rows of millet. Mulch was laid down within one hour after soil fumigation. Mulches used were aluminum, blue, and white Polyagro plastic (Poly Printers, Inc., Bridgeport, PA) and EZ Mulch brown paper (Gulf States Paper Corp., Oneco, FL) coated on both sides with transparent polyethylene film. Two weeks after mulching, 2 rows of holes 30 × 30 cm apart were cut in the mulch to allow ventilation. One week later, squash was planted 3 seeds/hole. Planting dates were August 14 and 18 in 1973 and 1974, respectively.

Plots received water based on 2 sets of 2 tensionmeters placed at 15 and 30 cm depths in the soil under the mulches at 4 different locations. Irrigation began when tension reached 0.25 bars at the 15 cm level and was turned off before the soil became saturated at the 30 cm level.

Mineral oil (Volck Supreme) treatments were applied (18.7 liters in 467 liters water/ha) by hand at weekly intervals. Carbofuran was applied 2.24 kg ai/ha in 1868 liters water/ha) in 1973 as a drench to the base of the newly emerged seedlings. Pesticides (benlate benomyl or maneb) for foliage disease control were applied at weekly intervals with an air-blast sprayer in 467 liters water/ha according to recommendations by the Univ. of Georgia Extension Service.

Aphid populations were estimated from 30 cm square yellow-pan water traps (17) placed in the centers of the main plots (mulches). Aphids were collected from the pans on various dates and counted, but species were not determined. Plants were examined during the growing season (Sept. 25, Oct. 16 in 1973, and Oct. 1, 10 and Nov. 9 in 1974) for symptoms of virus infection and serpentine leafminers. Soil samples (20 cores – 2.1 × 20 cm) were collected from the root zone 18 days after planting in 1973 and 1974, respectively, and after the final harvest for nematode assays. Soil samples were mixed thoroughly, and a 150 cc aliquot was processed by a centrifugal flotation method (16) to separate nematodes from the soil. Ten plants/plot were also indexed on a 1–5 scale (1 = 0 galls, 2 = 1–25, 3 = 25–50, 4 = 50–75, 5 = 75–100% roots galled) after final harvest.

Roots were examined for root rots in 1973 by examining 10 plants/plot for root and hypocotyl discoloration and decay on September 18, 36 days after planting. In 1974, plants were not examined as above, but soil under brown paper mulch was assayed for soil fungi 1 day before planting.

Fruit was hand harvested from a 6.1 m center section of each plot at 3–4 day intervals (Sept. 17 through Oct. 22 in 1973, Oct. 4 through Nov. 11, 1974), counted, weighed and examined for rots, physical and color abnormalities, pickleworms, and symptoms of virus (7).

Results and Discussion

There were no significant differences in numbers of decayed or physically abnormal fruit; therefore, data are not included.

Virus disease. Virus disease, based on fruit symptoms, was 100% WMV and was not extensive on the fruit (Table 1) or plants (Table 2). All film mulches significantly reduced obser-

Table 1. Effect of film mulch and pesticides applied to the soil and/or foliage on watermelon mosaic virus infection of yellow summer squash fruit, Tifton, Ga.

	% fruit with WMV symptoms										
	1973						1974				
	Mulched						Mulched		Nonmulched		
Treatment	Alum. plastic	White plastic	Blue plastic	Brown paper	Non-mulched check	Mean sub plot	Alum. plastic	Brown paper	Millet barrier	Check	Mean sub plot
DD-MENCS	1.5a[z]	0.8a	.5a	1.6a	12.2b	3.3b	1.6a	2.5a	3.2a	5.8ab	3.3a
Carbofuran	–	–	–	–	–	–	.5a	.5a	3.5a	.9a	2.4a
DD-MENCS + oil	.5a	.7a	1.1a	.8a	1.5a	.9a	3.9a	1.4a	3.6a	3.6a	3.2a
DD-MENCS + carbofuran	1.8a	1.3a	.9a	.7a	1.3a	1.2ab	2.1a	.5a	4.7a	3.6a	2.8a
DD-MENCS + carbofuran + oil	.6a	.9a	1.6a	.3a	2.5a	1.2ab	1.1a	2.4a	2.9a	4.5ab	2.8a
Sodium azide	1.1a	2.7a	1.3a	1.3a	5.6a	2.4ab	–	–	–	–	–
Carbofuran + sodium azide	–	–	–	–	–	–	2.5a	1.0a	5.8a	1.9a	2.9a
Nontreated check	1.1a	1.8a	2.2a	2.3a	2.6a	2.0ab	1.3a	1.4a	10.2b	10.4b	8.0b
Mean, main plot	1.1m[y]	1.4m	1.2m	1.4m	4.3n		1.8m	2.0m	5.9n	4.4n	

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

[y]Mean separation across rows by Duncan's multiple range test, 5% level.

Table 2. Effect of film mulch and pesticides applied to soil and foliage on watermelon mosaic (WMV), serpentine leafminer, and pickleworm on yellow summer squash, Tifton, GA.

Treatments	No. plants with virus symptoms	Serpentine leafminers		% fruit damaged by pickleworms
		No./leaf	% leaves infested	
	1974	1973	1974	1973
Mulch (main plot)				
Aluminum plastic	2.9ab[z]	2.6a	33a	0.9ab
White plastic	–	2.6a	–	1.1ab
Blue plastic	–	3.7a	–	1.2ab
Brown paper	2.4a	3.4a	33a	1.6b
Millet barrier	4.2b	–	57b	–
Check	6.0c	7.8b	54b	0.6a
Pesticide (sub plot)				
DD-MENCS	4.6a	5.4b	62ef	1.3ab
Carbofuran	3.8a	–	42cd	–
DD-MENCS + oil	2.6a	4.1ab	52de	1.2ab
DD-MENCS + carbofuran	4.6a	3.5a	24ab	0.7a
DD-MENCS + carbofuran + oil	3.6a	3.8ab	20a	0.9a
Sodium azide	–	3.9ab	–	1.4b
Carbofuran + sodium azide	4.4a	–	34bc	–
Nontreated check (none)	4.4a	3.6ab	74f	0.8a

[z]Mean separation within columns by Duncan's multiple range test at the 5% level.

vable WMV symptoms in both fruits and plants. The millet barrier caused a significant reduction in % WMV infected plants but did not affect the percentage of infected fruits.

In 1973, chemical treatments had no significant affect on reducing WMV symptoms on the fruit (Table 1) or plants (Table 2). In nonmulched plots fumigated with DD-MENCS, there were significantly more WMV infected fruit than in the non-treated check. Treated plants were taller and appeared more vigorous than non-treated plants and may have been more attractive to incoming vectors. In 1974, the % of fruit showing WMV symptoms was significantly lower than the untreated check in nonmulched plots treated with the systemic insecticide carbofuran and/or mineral oil (Table 1). Any effect these treatments had in the mulched plots was probably superceded by the influence of the film mulches. The mulches by nature of their aphid repellency reduced primary virus spread by preventing immigrant vectors from settling on the plants. Apparently, carbofuran and mineral oil reduced secondary spread of WMV within the field.

The effect of film mulches in reducing WMV spread is paralleled by aphid catches (Table 3). Numbers of aphids were reduced over aluminum plastic mulch in 1973. In 1974, aphid catches were reduced by brown paper and aluminum plastic until Oct. 25 when their reflective surfaces were obscured by vine growth. Aphid catches then increased rapidly until Nov. 1, one week before large numbers of plants exhibited WMV symptoms and 2 weeks before a killing frost occurred.

Table 3. No. of aphids captured in 30 cm yellow water trap as influenced by mulch treatments, Tifton, GA.

Date	Mean no. aphids/trap						
	Alum.	White	Blue	Brown	Millet	Check	Mean
1973							
Sept. 6	4	6	13	5		6	5.7
13	0	5	5	9		7	4.3
25	7	7	0	6		14	6.7
Total	11	18	24	20		21	
1974							
Sept. 27	4			10	47	40	25.2
Oct. 1	1			2	7	5	3.8
4	0			1	1	3	1.2
7	5			4	5	6	5.0
12	7			10	15	9	10.2
18	8			10	17	37	18.0
25	30			42	48	52	43.0
Nov. 1	120			120	115	128	120.8
9	340			395	533	375	410.8
Total	515			594	785	655	

The low aphid pressure observed during both years probably accounts for the low incidence of virus disease during the experiment (4.3% infected fruit in the nonmulched plots during each year) and contrasts sharply with observations in commercial fields elsewhere where over one-half of the fruits were infected.

Effectiveness of the aluminum film mulch was reduced by the progressive loss of the aluminum material which was sprayed on one surface of the black plastic by the manufacturer. A similar experience was reported by Johnson et al. (17) who obtained better results with aluminum foil bonded to paper. The effectiveness of brown paper mulch in reducing WMV was probably due to the moderate reflectiveness of the plastic surface coating.

Insects. Brown paper mulch significantly increased pickleworm infestation in 1973 (Table 2). All mulches reduced serpentine leafminer infestation ca. 50% during both years. Interactions between main plots and pesticides were nonsignificant and are not shown. In 1973, DD-MENCS-fumigated plots receiving carbofuran drench had significantly fewer leafminers per leaf than DD-MENCS plots without carbofuran. In 1974, carbofuran granules significantly reduced the percentage of plants infested with leafminers.

The reduction of serpentine leafminers and increase of pickleworms by reflective mulch agree with previous results (29) and suggests that some insect species are repelled while others are attracted to reflective surfaces. Film mulch may also act as a barrier to pupating leafminer larvae that drop from infested leaves to the soil. The effects of carbofuran granules in reducing infestation may be due to both systemic action in the plant and contact action in the soil.

Nematodes. Populations of plant-parasitic nematodes were not significantly affected by film mulch and only the chemical split-plot treatments results are shown (Table 4). Plant-parasitic nematodes obtained in significant numbers were *Criconemoides ornatus* Raski (ring nematode), *Meloidognyne incognita* (Kofoid and White) Chitwood (root-knot nematode), and *Trichodorus*

Table 4. Effect of soil fumigants on populations of plant parasitic nematodes infesting yellow squash, Tifton, GA.

Treatment	No. of nematodes/150 cc soil								Root-gall indices[z]			
	1973				1974				1973		1974	
	Sept. 18		Nov. 5		Aug. 28		Nov. 9					
	Ring	Root knot	Ring	Root knot	Ring	Root knot	Ring	Root knot	Sept. 18	Nov. 5	Oct. 1	Nov. 9
DD-MENCS	1a[y]	0a	0	230a	3a	8a	1a	78a	1.3a	1.8a	2.0a	2.5bc
Carbofuran	–	–	–	–	13b	49b	14b	681b	–	–	3.6c	3.7cd
DD-MENCS + oil	1a	1a	0	378a	3a	6a	0a	187a	1.5ab	2.0a	2.0a	2.9cd
DD-MENCS + carbofuran	0a	1a	5	502a	1a	4a	0a	29a	1.3a	1.6a	1.6a	1.0a
DD-MENCS + carbofuran + oil	1a	4a	0	464a	4a	7a	1a	51a	1.3a	1.7a	1.7a	1.3ab
Sodium azide	2ab	28b	8	222a	–	–	–	–	1.9b	4.2c	–	–
Carbofuran + sodium azide	–	–	–	–	9ab	50b	14b	581b	–	–	3.4b	4.1cd
Nontreated check	7b	18b	–	408a	14b	122c	6a	716b	1.9b	3.7b	5.0d	4.7d

[z]1–5 scale: 1=no galls, 2=1–25, 3=25–50, 4=50–75, and 5=75–100% roots galled.

[y]Mean separation within columns by Duncan's multiple range test, 5% level. Absence of letters indicates nonsignificance.

christiei Allen (stubby-root nematode). Small populations of stubby-root nematode in 1973 (data not shown) and ring nematodes in 1973 and 1974 were controlled with DD-MENCS. DD-MENCS controlled root-knot nematodes and root galling during the early growing season in both years.

Soil-borne fungi. Root diseases were negligible in 1973. Only 7 of 1200 plants examined had discoloration of roots and/or hypocotyls (data not shown). Disease did not affect plant stand.

In 1974, soil under brown paper was assayed for soil fungi 1 day before planting. Populations of *Fusarium solani* (Mart) Appel & Wor., *F. oxysporum* Schlecht, emend Snyd. & Hands., and total populations of *Fusarium* spp. were significantly reduced in all DD-MENCS treated plots as compared with non-fumigated control (Table 5). Carbofuran and sodium azide did not significantly reduce populations of *Fusarium* spp.

Populations of *Pythium* spp. were low in all plots (<13 propagules/g of oven-dry soil), and fumigation with DD-MENCS did not significantly reduce populations below that in the control.

Yield. Film mulch increased squash yields from about 70% to more than 600% over nonmulched plots depending on soil pesticide (Table 6). Effects of film mulch were greatest in non-treated plots. When yield was averaged across treatments, color of film mulch showed no significant effect. However, in 1973, when compared in non-fumigated plots, aluminum and white plastic were significantly better than brown paper or blue

Table 5. Influence of soil pesticides under brown paper film mulch on populations of soil-borne fungi, Tifton, GA.

Treatment	Propagules/g oven dried soil			
	Pythium spp.	*Fusarium solani*	*Fusarium oxysporum*	Total *Fusarium* spp.
DD-MENCS	0a[z]	0a	0a	19a
Carbofuran	8.5c	1701b	1925b	3869b
DD-MENCS + oil	3.2ab	206a	392a	635a
DD-MENCS + carbofuran	0a	168a	19a	206a
DD-MENCS + carbofuran + oil	1.1ab	19a	0a	56a
Carbofuran + sodium azide	4.2ab	916b	1084b	2149b
Nontreated check	5.3abc	1234b	2000b	3514b

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

Table 6. Effect of film mulch and pesticides applied to the soil and/or foliage on total yield of yellow summer squash, Tifton, Ga.

Treatment	Gross yield (MT/ha)										
	1973						1974				
	Alum. plastic	White plastic	Blue plastic	Brown paper	Non-mulched check	$\bar{X}$ all sub plots	Alum. plastic	Brown paper	Millet barrier	Check	$\bar{X}$ all sub plots
DD-MENCS	34.2a[z]	32.4b	34.0b	30.9bc	15.0bc	29.3cd	28.2ab	29.0c	14.0b	17.6b	22.2cd
Carbofuran	–	–	–	–	–	–	25.3a	25.2abc	7.4a	7.0a	16.2b
DD-MENCS + oil	31.9a	30.8b	27.0a	32.4c	10.2ab	26.9bc	27.8ab	26.1abc	18.7b	16.8b	22.4cd
DD-MENCS + carbofuran	37.8a	36.6b	30.2ab	34.4c	19.6c	31.7d	31.4b	28.3bc	19.0b	18.1b	24.2d
DD-MENCS + carbofuran + oil	32.2a	31.9b	30.9ab	35.0c	15.9bc	29.2cd	30.6b	27.6bc	16.0b	15.0b	22.3cd
Sodium azide	29.1a	25.1a	31.2ab	26.1ab	10.1ab	23.9a	–	–	–	–	–
Carbofuran + sodium azide	–	–	–	–	–	–	28.8ab	23.6ab	7.8a	5.7a	16.5b
Nontreated check	33.4a	35.6a	25.0a	22.2a	4.7a	24.2a	24.1a	21.6a	4.4a	3.7a	13.4a
Mean, main plot	33.1n[y]	29.7n	3.1n	30.2n	12.6m		27.9n	25.6n	12.7m	12.6m	

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

[y]Mean separation in rows by Duncan's multiple range test, 5% level.

plastic. The positive effects of white and aluminum plastic film mulch may have been related to their greater reflectivity which would have caused a greater reduction in soil temperature than blue or brown, and which could have had a significant influence on the mass of feeder roots located near the soil surface under the film mulch.

All soil treatments, except sodium azide in 1973, produced significant average increases in yield over the nontreated checks (Table 6). Plots treated with carbofuran alone, sodium azide alone, and carbofuran plus sodium azide were significantly poorer than treatments receiving DD-MENCS, probably because of the failure of carbofuran and sodium azide to effectively control nematodes (Table 4) and soil fungi (Table 5).

The effects of soil pesticides on squash yield varied among the different mulches and between mulched and unmulched plots (Table 6). Under aluminum plastic, none of the treatments were significantly better than the nontreated check except DD-MENCS + carbofuran in 1974. Under brown paper, all treatments except those with sodium azide were significantly better than the check. In nonmulched plots, treatments without DD-MENCS fumigation were not significantly different from the nontreated check.

Our research confirms and extends previous research (5, 15, 26) that film mulch and trickle irrigation can markedly increase yields of summer squash even under sub-optimum conditions. Although soil fumigation significantly increased yields in nonmulched plots, its effect was negligible under film mulch and mulch could easily substitute for fumigation as indicated by the lack of significant differences among soil treatments under aluminum. Soil fungi and nematodes were present in high numbers under nontreated mulch but their deleterious effects were somewhat masked by the improved soil moisture and nutrition available to plants grown in the film mulch-trickle irrigation system. The abundant root system was concentrated at the soil surface under the film mulch and was sufficient to overcome any stress induced by soil pathogens so long as adequate moisture and nutrients were delivered through the irrigation system.

Literature Cited

1. Adlerz, W. C. and H. P. Everett. 1968. Aluminum foil and white polyethylene mulches to repel aphids and control watermelon mosaic. *J. Econ. Entomol.* 61:1276-1279.
2. Black, L. M. and L. H. Rolston. 1972. Aphids repelled and virus diseases reduced in peppers planted on aluminum foil mulch. *Phytopathology* 62:747 [Abstr.]
3. Broadbent, L. 1969. Disease control through vector control. Pages 543-560 *In* K. Maramorosch (ed.) Viruses, vectors, and vegetation. Interscience Publishers, N.Y.
4. Chalfant, R. B. 1969. Control of the poplar petiole gall aphid on turnip roots. *J. Econ. Entomol.* 62:1519.
5. Courter, J. W. and N. F. Oebker. 1964. Comparisons of paper and polyethylene mulching on yields of certain vegetable crops. *Proc. Amer. Soc. Hort. Sci.* 85:525-531.
6. Crane, G. L. and L. Calpouzos. 1969. Suppression of symptoms of sugar beet virus yellows by mineral oil. *Phytopathology* 59:697-698.
7. Demski, J. W. 1972. Symptoms in squash induced by Georgia virus isolates. Ga. Agr. Expt. Sta. Bul. 58.
8. Dutrecq, A. and J. Vanderveken. 1969. Persistence of the inhibitory effect of oil on the transmission of beet yellows virus by *Myzus persicae. Bul. Rech. Agron. Gemblour* 4:66-75. [*Biol. Abstr.* 51: 069418.]
9. Gay, J. D., A. W. Johnson, and R. B. Chalfant. 1973. Effects of a trap crop on the introduction and distribution of cowpea virus by soil and insect vectors. *Plant Dis. Rptr.* 57:684-687.
10. George, W. L. and J. B. Kring. 1971. Virus protection of late-season summer squash with aluminum mulch. *Conn. Agr. Expt. Sta. Cir.* 239.
11. Heathcote, G. D. 1968. Protection of sugar beet sticklings against aphids and viruses by cover crops and aluminum foil. *Plant Path.* 17:158-161.
12. ———. 1973. Control of viruses spread by invertebrates to plants. p. 487-609 *In* A. J. Gibbs (ed.) Viruses and invertebrates. American Elsevier.
13. Hein, Alice. 1970. Zur wirkung von Öl auf der Virusübertragung durch Blattläuse. *Phytopathol. Z.* 71:42-48.
14. Jadot, R. and J. Vanderveken. 1973. Effect of oil spray on spread of sugar beet viruses. *Meded Fac. Landbouwet Rijksuniv. Gent.* 38:1677-1683. [*Biol. Abstr.* 59:27679.]
15. Jaworski, C. A., A. W. Johnson, R. B. Chalfant, and D. R. Sumner. 1974. A system approach for production of high value vegetables on southeastern coastal plain soils. *Ga. Agr. Res.* 16(2):12-15.
16. Jenkins, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. *Plant. Dis. Rptr.* 48:692.
17. Johnson, G. V., A. Bing, and F. F. Smith. 1967. Reflective surfaces used to repel dispersing aphids and reduce spread of aphid borne cucumber mosaic virus in gladiolus plantings. *J. Econ. Entomol.* 60:16-19.
18. Kring, J. B. 1972. Flight behavior of aphids. p. 461-492 *In* R. F. Smith and T. E. Mittler (eds.) *Annu. Rev. Entomol.* Vol. 17.
19. Kulps, G. 1968. Untersuchungen zur Schutywirkung von Ölen bei der Virusübertragung durch Blattläuse. *Z. Pflanzenkraukh. (Pflanzenpathol) Pflanzenschutz* 75:213-217.
20. Loebenstein, G., M. Alper, and S. Levy. 1970. Field tests with oil sprays for the prevention of aphid-spread viruses in peppers. *Phytopathology* 60:212-215.
21. Moore, W. D., F. F. Smith, G. V. Johnson, and D. O. Wolfenbarger. 1965. Reduction of aphid population and delayed incidence of virus infection on yellow straight neck squash by the use of aluminum foil. *Proc. Florida Hort. Soc.* 78:187-191.
22. Russell, G. E. 1970. Effects of mineral oil on *Myzus persicae* and its transmission of beet yellows virus. *Bul. Entomol. Res.* (Berea) 59: 691-694.
23. Smith, F. F., A. L. Boswell, and R. E. Webb. 1972. Repellent mulches for control of gladiolus thrips. *Environmental Entomol.* 1: 672-673.
24. ——— and R. E. Webb. 1969. Repelling aphids by reflective surfaces; a new approach to the control of insect transmitted viruses. p. 631-639 *In* K. Maramorosch (ed.) Viruses, vectors and vegetation. Interscience Publishers, N.Y.
25. Sumner, D. R., A. W. Johnson, C. A. Jaworski, and R. B. Chalfant. 1974. Control of soil-borne pathogens in vegetables with fumigation and film-mulch. *Amer. Phytopatholog. Soc. Proc.* 1:167 [Abstr.]
26. Vanderveken, J. and A. Dutrecq. 1970. Contribution to the study of the inhibitory effects of a mineral oil on the aphid transmission of plant viruses. *Ann. Phytopathol.* (Anpt B) 2:287-402.
27. Watson, M. A. and R. T. Plumb. 1971. Transmission of plant-pathogenic viruses by aphids. *Ann. Review Entomol.* 17:425-432.
28. Wolfenbarger, D. O. and W. D. Moore. 1968. Insect abundance on tomatoes and squash mulched with aluminum and plastic sheetings. *J. Econ. Entomol.* 61:34-37.