Effect of Cultured Cuttings, Fumigation, and Mulching on CARNATION FLOWER PRODUCTION

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EFFECT OF CULTURED CUTTINGS FUMIGATION, AND MULCHING ON CARNATION FLOWER PRODUCTION

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INTRODUCTION

Diseases are among the major problems of carnation culture in Hawaii. Carnations are a perennial crop often cultivated for 2 to 3 and sometimes 4 years in mainland greenhouses; however, at low elevations in Hawaii, field culture is not profitably extended beyond the first harvest year because of heavy plant mortality. Nakasone and Kamemoto (1957) observed approximately 50 percent survival of the Common Pink variety after a harvest year in a field cropped with carnations for the first time. Hendrix and Murakishi (1950) recorded as low as 1 percent stand of Common Pink in a 12-month-old field in the Koko Head area in Honolulu, where carnations had been cultivated continuously. Hendrix and Murakishi isolated *Fusarium dianthi, Alternaria dianthi, Rhizoctonia solani, Sclerotium rolfsii, Phytophthora* sp., and *Colletotrichum* sp. from diseased carnation plants.

Because soil-borne diseases are mainly responsible for the heavy mortality and reduced yields of field-grown carnations, soil treatments eliminating or reducing the population of the disease-causing organisms, barring recontamination, should increase longevity and productivity. By treating soil with chloropicrin or formaldehyde in propagation beds, Hendrix and Murakishi (1950) were able to reduce the incidence of post-rooting mortality.

Recently, methyl bromide fumigation has become a recommended and established practice for many floricultural and olericultural crops in Hawaii, because of its effectiveness in controlling soil diseases and weeds and its ease of application. Despite the reported phytotoxicity of methyl bromide on carnations (Williamson, 1953), some island carnation growers have successfully used this material.

Beneficial effects of soil fumigation can be completely nullified if pathogens are introduced into the field through infected plant material. The "culturing" of cuttings has become a standardized technique (Tammen *et al.*, 1956) in producing cuttings free from systemic diseases in many ornamentals including carnations. Today, a grower can procure cultured carnation cuttings from any reputable nursery on the Mainland. However, cultured cuttings for the Common Pink and Uniwai varieties, grown exclusively in Hawaii for leis, are not yet commercially available.

With the realization that soil-borne diseases have been the limiting factor in the production of carnations in Hawaii, the Plant Pathology and Horticulture Departments conducted cooperative experiments on the effects of cultured cuttings and soil fumigation on flower production of Common Pink and Uniwai varieties. Tests on mulching along with fumigation and toxicity of methyl bromide were also carried out.

CULTURED CUTTINGS AND FUMIGATION

Materials and Methods

Cultured cuttings were established through the following procedure: Cuttings were selected from the most vigorous field plants which were free from obvious disease symptoms. A disc from the basal end of the stem was surface-sterilized for 1 minute with a 1 percent solution of hypochlorite and placed on potato dextrose agar. If after 48 hours no growth of microorganism was evident, the cutting from which the disc was obtained was presumed to be free from pathogenic organisms. These "pathogen-free" cuttings were rooted individually in vermiculite and later transplanted into sterilized soil in individual pots to serve as the nucleus block. Cuttings were taken from these plants, rooted, and established in steam-sterilized soil to serve as the increase block to provide sufficient cuttings for this and subsequent tests. Cultured plants of Common Pink and Uniwai were established in this way.

In order to compare the performance of cultured cuttings and non-cultured field-obtained cuttings, both types from the variety Uniwai were propagated separately under mist, then transplanted into 3-inch plant bands containing steam-sterilized soil. After the plants became well established, they were transplanted into the field.

Methyl bromide and Vapam were selected for the test because of their effectiveness in controlling weeds as well as some disease organisms. Methyl bromide was applied at 1, 2, and 4 pounds per 100 square feet, while Vapam was applied at 50, 100, and 150 gallons per acre. The methyl bromide was applied by puncturing the container under a plastic cover over the beds. Vapam was applied by pouring the required amount of liquid on the plots, roto-tilling, and finally wetting down the soil with water.

Fumigation treatments were randomized in four complete blocks. Individual plots, 3 feet × 14 feet, were split into 3 feet × 7 feet to test both cultured and noncultured cuttings. Each split-plot contained three rows of seven plants each, or 21 plants, and a total of 1,176 plants were employed in the test.

Good horticultural practices, including regular fertilization and frequent irrigation, were followed during the test to maintain vigorous plants. Biweekly spraying, including DDT, sulfur, and zineb (Dithane Z-78 or Parzate), were made to control insects, mites, and foliar diseases.

Observations on phytotoxicity of fumigants, weed growth, and mortality of carnations were made periodically. Flowers were harvested semiweekly and recorded. At the beginning of each month, stems which had completed their flowering were cut back to promote new growth.

Results

It was established by symptomatology, isolations, and inoculations that the principal pathogens causing carnation mortality in these and subsequent tests were *Fusarium oxysporum* f. *dianthi* and *Pseudomonas caryophylli*. After 1 year of culture, there were no significant differences in stand due to fumigation treatment or to type of cutting used. However, significantly better yields were obtained with cultured cuttings and with both fumigants (table 1).

TABLE 1. Effect of cultured cuttings and fumigation on yield (number) of flowers during 1 year of culture

FUMIGANTS AND RATES	NUMBER OF FLOWERS			
	Cultured cutting	Field cutting	Plot total	Plot average
Methyl bromide (1 lb/100 sq ft)	10,200	10,100	20,300	5,100[c]*
Methyl bromide (2 lb/100 sq ft)	9,500	9,000	18,500	4,600[bc]
Methyl bromide (4 lb/100 sq ft)	9,300	8,200	17,500	4,400[ab]
Vapam (50 gal/acre)	10,000	9,200	19,200	4,800[bc]
Vapam (100 gal/acre)	10,200	9,500	19,700	4,900[c]
Vapam (150 gal/acre)	10,200	9,700	19,900	5,000[c]
Control	8,500	7,900	16,400	4,100[a]
Total	67,900†	63,600†	131,500	

*Treatment differences are statistically significant (5 percent level) if they are not followed by the same superscript letter (Duncan's Multiple Range Test, 1955).

†The difference is statistically significant (5 percent level).

All fumigation treatments resulted in an increase in flower yield over the unfumigated controls, although the difference in yield between methyl bromide at 4 lb/100 sq ft and the control was not statistically significant. It can be seen from table 1 that an increase in dosage of Vapam resulted in a slight, corresponding increase in yield which is not statistically significant; with methyl bromide there was an inverse relationship between dosage and flower yield due to the phytotoxicity of methyl bromide. The

FIGURE 1. Carnation plant showing severe injury caused by methyl bromide preplant fumigation.

heaviest dosage of methyl bromide caused mortality of some plants and severe injury to others. In one split-plot, 17 of the 21 plants were severely damaged, 11 of which eventually recovered. Early symptoms of affected plants were the bleaching of stem and leaves resulting in a scalded appearance and death of the entire affected tissue (fig. 1). The injury by methyl bromide at 1 lb/100 sq ft and 2 lb/100 sq ft was less severe, and total yield was not seriously affected. Actually, the highest yield from different treatments was obtained from plots treated with 1 pound of methyl bromide.

The yield from plots planted to cultured cuttings averaged 7 percent more than that from uncultured cutting plots. In every fumigation treatment, cultured cuttings outyielded field cuttings. It may be of interest to note that the highest yield from the combined treatments of fumigation and cultured cuttings (methyl bromide at 1 lb/100 sq ft and Vapam at 100 and 150 gal/acre) exceeded the yield of unfumigated field cuttings by 29 percent. Monthly cumulative yields, as illustrated graphically in figure 2, point out these yield differences.

Complete weed control was obtained with methyl bromide fumigation and partial control with Vapam. The unfumigated plots, on the other hand, were badly infested with weeds which required constant attention.

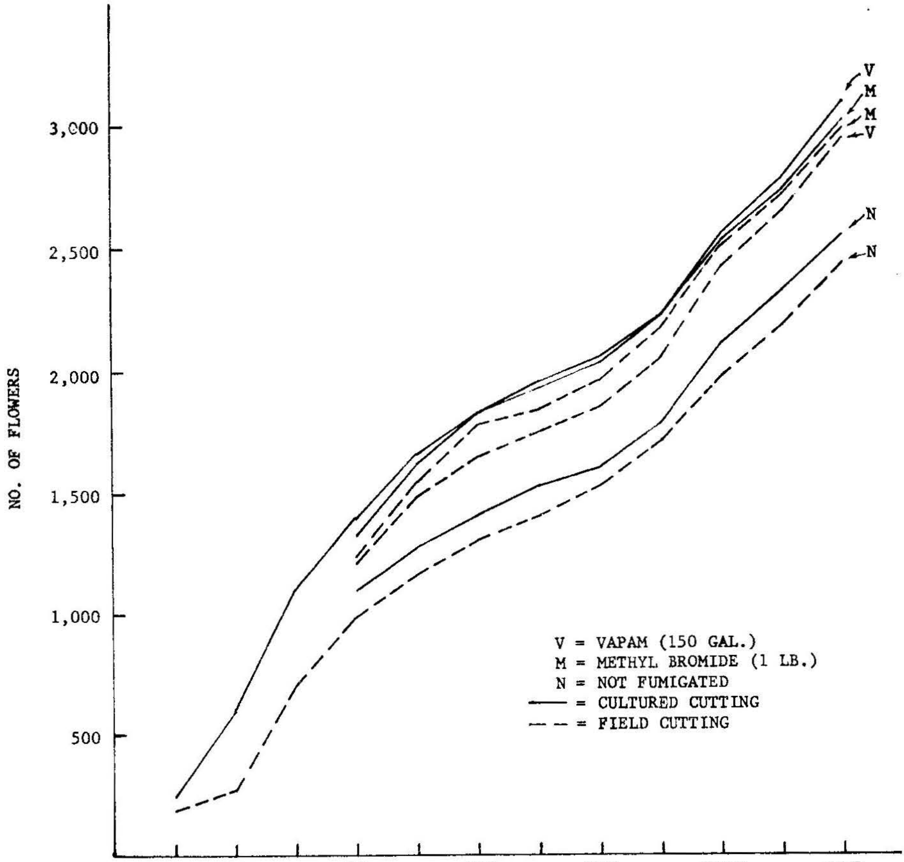

FIGURE 2. Cumulative yields (per split-plot) of carnation blossoms showing the effects of fumigation and cultured cuttings. Lower portions of all curves are not shown because they nearly coincide during the early months.

THE INFLUENCE OF FREQUENCY OF IRRIGATION AND THE ADDITION OF BAGASSE TO SOIL ON PHYTOTOXICITY OF METHYL BROMIDE TO CARNATIONS

Materials and Methods

Because the severity of toxicity of methyl bromide to carnations under field culture was variable, an experiment was conducted in the greenhouse to determine whether moisture and organic content of the soil affect methyl bromide toxicity, as suggested by Williamson (1953). Five established plants from cultured cuttings of Common Pink grown in a deep flat constituted a treatment unit, and treatments were randomized in two replicates.

Field soil from the University of Hawaii farm area was mixed well and divided into two lots. One lot was mixed with bagasse on a volume basis at a ratio of 3 parts soil to 1 part bagasse. The soil was then put into flats, and half of each lot was fumigated with methyl bromide at the rate of 4 lb/100 sq ft.

The plastic cover was removed after 24 hours and plants were transplanted 11 days later.

Irrigations were made daily, three times a week (Monday, Wednesday, Friday), twice weekly (Monday, Friday), and weekly. These treatments were initiated about a month after transplanting.

The plants were examined carefully at least three times a week to record onset of symptoms and death.

Results

Symptoms of methyl bromide injury appeared on every plant from the fumigated lot as early as 15 days and as late as 111 days from time of transplanting. The first signs were water-soaked areas on single leaves which soon took on a bleached appearance with an advancing water-soaked margin. Several leaves were affected on some plants, shoots on others, and in the severest cases entire plants were killed.

The symptoms appeared significantly sooner on plants growing in plain soil as compared with plants in the bagasse-soil mixture (table 2). The plants also died rapidly in plain soil as compared with those in bagasse-soil, but this difference was not statistically significant. No significant differences were noted among the different irrigation treatments, although there were indications that the irrigation schedules which were conducive to best growth hastened the onset of symptom expression. In general, the more severely affected plants in the fumigated series were in treatments which produced higher top weights in comparable nonfumigated treatments.

TABLE 2. Number of days from transplanting to the appearance of methyl bromide injury (per plant average) and the number of plants (of 10) killed by methyl bromide toxicity

IRRIGATION SCHEDULE	NUMBER OF DAYS			NUMBER OF PLANTS KILLED		
	Soil	Soil + bagasse	Average	Soil	Soil + bagasse	Total
Daily	39	59	49	3	1	4
MWF (3/week)	26	73	50	6	4	10
MF (2/week)	30	50	40	8	8	16
M (1/week)	40	83	62	8	1	9
Average	34*	66*	Total	25	14	39

*The difference is statistically significant (5 percent level).

THE INFLUENCE OF FUMIGATION WITH CHLOROPICRIN AND MULCHING ON CARNATION PRODUCTION AND SURVIVAL

Materials and Methods

It was previously shown (Nakasone and Kamemoto, 1957) that there was no difference in production and survival between mulched and unmulched carnation plots; however, a mulching trial with cultured cuttings and fumigated plots seemed desirable because of possible benefits if these factors are combined.

The mulches tested were white (opaque) plastic, black plastic, and bagasse. Mulch treatments were randomized in four complete blocks. Individual plots, 3 feet $\times$ 14 feet, were split into 3 $\times$ 7 plots to test fumigant effect. Chloropicrin was used at 800 lb/acre. The test plant was Common Pink; 21 well-established plants started as cultured cuttings were planted per split-plot.

Field cultural practices were followed as previously described in the first field experiment. Data were collected also as described earlier.

Results

During the 2-month period immediately following transplanting, the plants in white mulch treatment grew vigorously and rapidly. In fact, the growth was so vigorous that it was optimistically believed at that time that the treatment was better than others. However, plant growth in other treatments improved rapidly, and at the conclusion of the test there were no significant differences among the mulch treatments, despite the fact that the highest yield of 24,200 flowers was recorded for the white mulch treatment as compared with 21,400 flowers for the control.

The difference in yield, however, between fumigated and nonfumigated plants, was highly significant, and the results are summarized in table 3 and illustrated graphically in figure 3.

TABLE 3. Effect of mulch and fumigation on yield (number) of flowers during 1 harvest year

	NUMBER OF FLOWERS			
MULCH	Fumigated (chloropicrin 800 lb/acre)	Nonfumigated	Plot total	Plot average
White (opaque)	13,000	11,200	24,200	6,000
Black	12,400	10,500	22,900	5,700
Bagasse	12,100	10,100	22,200	5,500
None	11,700	9,700	21,400	5,300
Total	49,200*	41,500*		

*The difference is statistically significant at 1 percent level.

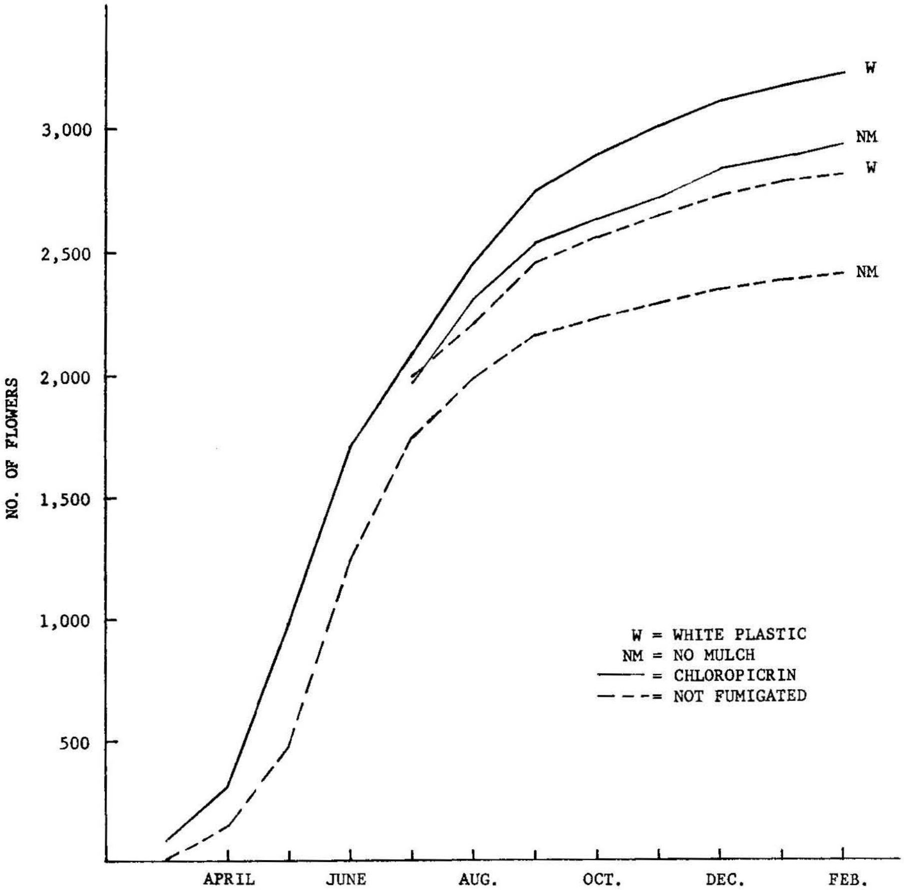

FIGURE 3. Cumulative yields (per split-plot) of carnation blossoms showing the effects of chloropicrin fumigation and mulching. Lower portions of all curves are not shown because they nearly coincide during the early months.

COMPARISON OF SOIL FUMIGANTS

Materials and Methods

A soil fumigation test conducted at a Koko Head farm revealed that some of the fumigants were promising for the control of soil-borne diseases of carnations (Aragaki and Ishii, 1960). However, no yield data were taken and the final stands were very low under the prevailing cultural conditions, and further testing under better controlled conditions was deemed advisable.

Infested soil from Koko Head was brought to the Plant Pathology greenhouse at the University of Hawaii and placed in deep flats. To simulate fumigation under field conditions, the flats were placed on the ground and fumigated with methyl bromide and chloropicrin under a plastic cover,

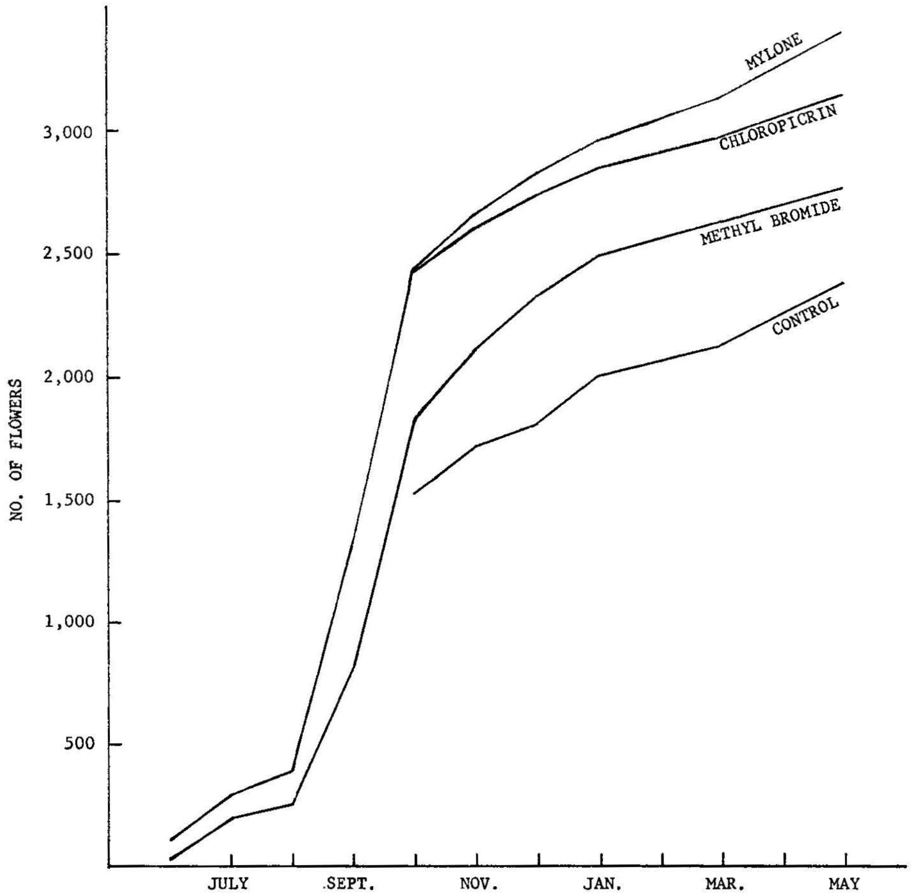

FIGURE 4. Cumulative yields of carnation blossoms showing differences due to fumigants. Lower portions of all curves are not shown because they nearly coincide during the early months.

rather than fumigating in sealed containers. The soil was thoroughly mixed with Mylone 85W, and watered. Methyl bromide was used at 1 lb/100 sq ft, chloropicrin at 800 lb/acre, and Mylone 85W at 400 lb/acre. The treatments were randomized in seven complete blocks and each flat was planted with six rooted, cultured cuttings of Common Pink. Flowers were harvested twice weekly and stand counts were made monthly. Notes on initial weed control were also made.

Results

For unknown reasons, sterilization was not achieved with the methyl bromide treatment. Weed control, final stand counts, and total yield were very poor, and only slightly better than the nonfumigated controls.

The fumigants, Mylone and chloropicrin, were outstanding from the standpoint of both weed control and total yield. The cumulative yields are summarized in table 4. The monthly cumulative yields are illustrated graphically in figure 4.

TABLE 4. Effect of fumigants on yield of flowers during 1 harvest year

FUMIGANTS	NUMBER OF FLOWERS Total	Average per flat
Mylone	3,389	484[a]*
Chloropicrin	3,137	448[ab]
Methyl bromide	2,761	394[bc]
Control	2,375	339[c]

*Treatment differences are statistically significant (5 percent level) if they are not followed by the same superscript letter (Duncan's Multiple Range Test, 1955).

DISCUSSION

The use of cultured cuttings increased total flower yield by only 7 percent over field-obtained cuttings. This slight difference can probably be attributed to the relatively healthy field cuttings obtained from experimental plantings of the Horticulture Department. Because the plots were fumigated and the plants were constantly sprayed with fungicides, the propagation materials seemed healthier than those in general use commercially. If cuttings were obtained from fields infested with the usual carnation disease organisms, the difference in performance between cultured and uncultured cuttings would undoubtedly have been magnified.

Cultured cuttings combined with fumigation treatments (1 lb methyl bromide/100 sq ft, and 100 and 150 gal Vapam/acre) gave 29 percent higher yields than uncultured cuttings in unfumigated plots. If the entire field were fumigated and grown with cultured cuttings, it is conceivable that an even higher yield might have been obtained, for with small, adjacent, randomized treatment plots the opportunities for recontamination are great.

During the course of the investigation, it was determined by observations, isolations, and inoculations that the diseases involved in the mortality of plants were principally Fusarium wilt (*Fusarium oxysporum* f. *dianthi*) and bacterial wilt (*Pseudomonas caryophylli*). There were no clear-cut differences in mortality between treatments, suggesting that recontamination might have occurred in the small plots. Also, it is possible that other organisms such as *Fusarium roseum* and *Alternaria dianthi* might have masked the treatment effects.

Methyl bromide at the commonly recommended dosage of 1 lb/100 sq ft, with the one exception cited above, gave increased yield of flowers despite the slight phytotoxic effects and also gave excellent weed control.

In a preliminary experiment, no injury was evident when carnations were planted only 2 days after fumigation with methyl bromide at 1 lb/100 sq ft. Some growers have used methyl bromide with success, although occasional, slight plant injury has been reported. Thus, at the dosage of 1 lb/100 sq ft, plant injury is often negligible. At 4 lb/100 sq ft, however, considerable damage and consequent reduction in yield can be expected. It has been shown that phytotoxicity manifests itself earlier in field soil than in bagasse-soil mixture, and at intermediate moisture levels than in either too-dry or too-wet conditions. According to Williamson (1953), plant injury is roughly proportional to (1) the colloidal content of the soil, (2) the soil temperature, and (3) the amount of methyl bromide applied. Greater toxicity was more evident with clay soils than with loam soil. No bromide injury was observed when sand, fumigated at the heavy dosage of 11 lb/100 sq ft, was planted with carnation cuttings 24 hours after fumigation.

Besides methyl bromide at 1 lb/100 sq ft, Vapam at all rates, chloropicrin, and Mylone 85W treatments at the dosages used resulted in significantly higher yields than from untreated plots. Of these fumigants, Mylone was outstanding in promoting increased yields, weed control, nonphytotoxicity, and ease of application. Despite some of its disadvantages, such as its corrosiveness and application difficulties, chloropicrin is excellent for disease control and could be used to good advantage.

The ranking of total yields in descending order of the mulch treatments were white plastic mulch, black plastic mulch, bagasse, and no mulch in both fumigated and unfumigated treatments. The differences between mulches were not statistically significant, due to the variations within treatments. The order of difference between white mulch and no mulch was about 11 percent. Where weeds and drought are problems, mulching would be beneficial. However, if plots are fumigated, the weed problem would be negligible, losing any advantage mulching would present.

SUMMARY AND CONCLUSIONS

A series of experiments on carnations involving cultured cuttings, fumigation, and mulching was conducted at the Hawaii Agricultural Experiment Station and resulted in the following findings:

1) The use of cultured cuttings resulted in a significant increase in flower yield of 7 percent as compared with that of field cuttings.

2) Fumigating fields infested with *Fusarium oxysporum* f. *dianthi* and *Pseudomonas caryophylli* with methyl bromide (1 lb/100 sq ft), Vapam (150 gal/acre), and chloropicrin (800 lb/acre) resulted in a significant increase in flower yield of approximately 20 percent over unfumigated controls.

3) Fumigating infested field soil (in flats) with chloropicrin (800 lb/acre) and Mylone 85W (400 lb/acre) resulted, respectively, in a significant increase in flower yield of 32 percent and 42 percent over that of unfumigated controls.

4) The combination of cultured cuttings with methyl bromide (1 lb/100 sq ft) or Vapam (150 gal/acre) fumigation increased the flower yield by 29 percent over noncultured cuttings in unfumigated plots.

5) An increase in dosage of methyl bromide from 1 lb to 2 lb and to 4 lb/100 sq ft resulted in a corresponding decrease in yield due to the increased phytotoxicity. At 1 lb/100 sq ft, however, injury was slight and the total yield was high.

6) Phytotoxicity symptoms of methyl bromide (4 lb/100 sq ft) appeared sooner in field soil than in soil-bagasse mixture. Also, onset of symptoms was hastened with the intermediate irrigation treatments which were conducive to good growth.

7) Mulching with white plastic, black plastic, and bagasse showed a tendency toward slightly higher yields than nonmulching, but the differences were not statistically significant.

Cultured cuttings used in conjunction with the fumigants, methyl bromide (1 lb/100 sq ft), Vapam (150 gal/acre), Mylone 85W (400 lb/acre), or chloropicrin (800 lb/acre), should result in increased yields of carnations under field culture in Hawaii; and this is the only effective and practical means of controlling Fusarium and bacterial wilts of carnation.

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