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INCREASED FLOWER PRODUCTION BY APPLICATION OF FUNGICIDES

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The increased cost of energy has made the steaming of greenhouse benches and beds an expensive operation. Therefore, it is necessary to reassess the value of steaming in the Colorado floricultural industry. Modern greenhouse management could eliminate the necessity of routine application of steam to soil because pathogen-free propagative material is now readily available. On the other hand, if problems in disease control are encountered, it may be possible to substitute less expensive methods, (for example, chemical or biological controls). Alternately, it might be possible to increase production with associated management practices to pay for steaming. This article describes progress toward the solution of the problems associated with these considerations.

The Value of Steaming in Modern Floriculture

For floricultural species, like carnation and chrysanthemum, pathogen-free propagative stock is available commercially. Thus, a grower using raised benches in production areas who has had no previous problems with diseases (like the vascular wilts or rots such as those induced by *Rhizoctonia solani)* should not necessarily have to resteam these benches before transplanting a new crop.

There are other considerations, however. Steaming of ground beds which are often infested with the vascular wilt pathogens, together with fumigation, provides significant increments of control. Even if no soil-borne pathogens are present, however, growers may consider the control of other pests, such as weeds, well-worth the cost and effort. Again, soil structure may be improved or maintained with periodic steaming. Another important factor is the observation that an increased growth response often results from steaming. What is the nature and mechanism of this response?

Research on the nature of the increased growth response observed when steam, fumigants or biocontrol agents are applied, has occupied the attention of a number of scientists for some time. In spite of intense research activity, however, a definitive explanation of mechanisms still is not available in the literature. Even so, certain conclusions and speculations may be drawn. The phenomenon appears to be associated with the eradication or reduced activity of certain microorganisms, some of which are known to be pathogens (depending on the environment or the susceptibility of the host during its life cycle). Concomitantly, increase in population density of other microbes following steaming or other treatments has been noticed. Some of these microorganisms proved to be antagonistic to pathogens and, indeed, stimulated plant growth when introduced into soil in high quantities.

Stimulation of plant growth has also been noticed when fungicides, specific in their action to pythiaceous fungi, were applied to soil. Members of the genus *Pythium* are known to invade root tips where meristematic (immature) cells are in abundance. These cells have thin walls which, under suitable conditions, provide a susceptible infection court. Areas of the root farther removed from the tip contain mature cells that are somewhat more resistant to penetration by *Pythium.* Thus, it is possible that root tips may be inactivated or rendered inefficient in their uptake of water and nutrients when infected by *Pythium* without the plant (as a whole) manifesting obvious symptoms.

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Such a situation, however, could result in reduced plant vigor. Treatments designed to eradicate or reduce the activity of *Pythium* should restore vigor and result in an increased growth response; therefore, steaming of greenhouse benches should eradicate this pathogen and thereby provide an explanation for increase in growth.

Table 1. Increase flower production and income resulting from application of steam and/or *Pythium*-inhibiting fungicides to soil planted with carnations

Grower designation	Experimental setup and variety	Frequency of application of fungicides[a]	Length of time records kept of flower production[b]	Treatments	Flowers cut per ft² [c] (during the time of the experiment)	Increase or decrease in income per ft² [c] (during the time of the experiment)
I	Raised benches. Planted June 23, 1979. White #1	Annually	664 days	Control, not steamed	51.6	
				Steamed only	51.2	—
				Ethazol only	53.9	+$0.37
				Steamed & ethazol	62.8	+$1.79
II	Ground beds treated with metam sodium (Vapam®). Planted Aug. 1 1980. Elliot's White	Semi-annually	1 year	Control[d]	31.0	
				Ethazol[d]	34.6	+$0.58
				Ridomyl	36.6	+$0.90
III	Ground beds. Planted June 5, 6, 1980. White #1	Semi-annually	267 days	Control, no steam[d]	36.3	
				Steamed ridomyl	37.7	+$0.32
				Ethazol only[d]	30.8	+$0.88
				Steamed & ethazol[d]	48.2	+$2.60
IV	Raised benches.					
	Planted July 5, 1980. CSU Red	Semi-annually	1 year	Control, steamed	39.3	
				Steamed + ethazol	43.5	+$0.67
	Planted July 3, 1980. Sir Elliot	Semi-annually	1 year	Control, steamed	36.9	
				Steamed + ethazol	39.9	+$0.48
	Planted July 1, 1980. White #1	Semi-annually	1 year	Control, steamed	34.0	
				Steamed + ethazol	35.7	+$0.27
	Planted July 3, 1980. Elliot's White	Semi-annually	1 year	Control, steamed	40.2	
				Steamed, ethazol	43.2	+$0.48
	Planted July 16, 1980. Coquette	Semi-annually	288 days	Control, steamed	33.1	
				Steamed, ethazol	38.1	+$0.83
V	Raised benches. Planted June 23, 1980. Crowley Pink Sim	Semi-annually	1 year	Control, steamed	47.6	
				Steamed + ethazol	49.7	+$0.34
				Steamed + ridomyl	40.0	-$1.21

[a] Fungicides applied at 18 oz/1000 ft², ethazol; 4 oz/500 ft², ridomyl.

[b] In some cases, these figures only represent first year production and records for the second year are currently being recorded.

[c] Figures represent cut and/or income only during the time stated in column 4 @ 16¢ per flower.

[d] In these cases ethazol was applied in combination with thiophanate as Banrot® at 32 oz/1000 ft² of material. In controls, only thiophanate was applied.

Substitution of Fungicides for Steam

There are fungicidal or fungistatic compounds available commercially or in the experimental stage which have activity against water molds like *Pythium.* One of these, ethazol, is commercially available under the trade name of Truban® as a 25% emulsifiable concentrate or 35% wettable powder. An experimental compound, ridomyl, also has activity against *Pythium* spp. Various experiments were begun in 1979 to determine the influence of these fungicides (applied to soils) on flower production in commercial greenhouses. Ethazol was applied as the emulsifiable concentrate at the rate of 18 oz/1000 ft² and ridomyl at 12.5 oz/1000 ft² of surface area at the time of transplanting and at various intervals thereafter.

The first experiments were done on raised beds. Flower production records were kept continuously and the basic experimental question asked was whether treatment with ethazol could substitute for the steam in inducing an increased growth response. The answer was in the affirmative. For example in a typical experiment, an increase in flower production of over 2 flowers/ft² was observed after 1 yr in benches treated with either steam alone or ethazol only in comparison with plants growing in soil that had not been treated. At the end of the first year, ethazol was applied again. After 664 days (when the experiment was terminated), the number of flowers cut in benches previously steamed was no greater than in the nontreated control; however, in the benches treated every year with ethazol an increase of almost 3 flowers/ft² was realized. The final results of this experiment are presented in tabular form in Table 1 under the grower designation of I.

These results suggest that steaming eradicated *Pythium* spp. which resulted in increased flower production during the first year. Reinfestation occurred, however, and eventually the steamed soil became recontaminated. The application of ethazol, however, reduced activity of *Pythium* spp. when it was applied at the beginning of the experiment and continued to do so during the course of the experiment. Population densities of *Pythium* spp. taken during the course of the experiment conformed and were correlated with this interpretation.

Thus, application of ethazol can replace steam for the induction of greater flower production and holds promise of having a continuing long-term effect in contrast to steaming.

Combining Steaming with Fungicide Treatments — an Unexpected Bonus

The experiment in the greenhouse of grower number I (Table 1) reproduced an unexpected result. A spectacular increase in flower production was observed over the control or any other treatment when ethazol was applied to previously steamed soils. This effect was noticed in another greenhouse also (see grower number III in Table 1). In this case there was an increase in almost 12 flowers/ft² in steamed ground beds treated with ethazol over the nontreated control during a 267 day period. If an average of 16¢/flower is realized, this is an increase of income of $2.60/ft².

Such a spectacular increase in production from the combined steam and ethazol treatments was not always observed when comparisons were made with soils which were only steamed; however, as illustrated by the experiments in the greenhouses of grower numbers IV and V, an increase in flower productions of from two to five per ft² was consistently observed.

So far the effects of ridomyl have been variable. An increase of over five flowers per ft² was realized with grower number II in ground beds previously only treated with metam sodium (Vapam®), whereas, a reduction of over seven flowers per ft² was observed in bed treated with ridomyl as compared with steamed controls for grower number V. However, this experiment included only one bench treated with ridomyl and it was a "gutter bench." Production is usually lower on such benches because of shading.

Variable results were also observed when eight cultivars of chrysanthemum were treated singly, in combination or without steam and/or ethazol (Fig. 1). In every case except Yellow Polaris, increase in average weight of flowers was observed, however, with some treatments (either alone or in combination).

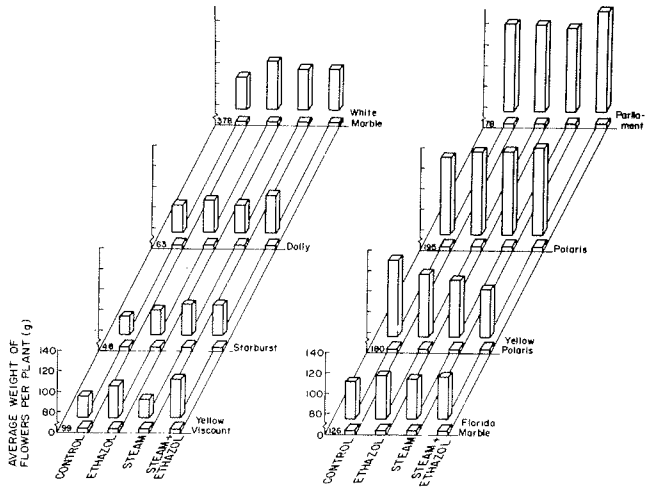

Fig. 1. Influence of soil treatment with steam and/or ethazol on chrysanthemum flower production. Numbers at the lower left margin of each graph indicate number of plants per treatment.

In experiments with carnations, increase in the average length of stems produced on the first crop was observed in fungicide treatments (range from approximately 2-4 inches) as compared with controls. Foliage often also had a deeper blue-green color and growth was "soft" and vigorous. As illustrated by flower counts, breaks were more numerous.

Steam plus the application of a *Pythium* inhibiting fungicide, thus, results in an increase in growth and flower production above that experienced when either one was used alone. Population density counts of *Pythium* spp. made during the course of the experiments may provide an explanation. Steaming eradicated the fungus. Ethazol or ridomyl decreased its population density but did not eradicate it completely. When ethazol or ridomyl was added after steaming, none or few colonies of *Pythium* species were detected over 1 or 2 yr periods. Evidently, once *Pythium* is eradicated, these fungicides effectively prevent recontamination.

To Steam or Not to Steam

From the results noticed in the experiments reported in this article, it is obvious that routine steaming of greenhouse soils combined with fungicide treatment is cost effective if only the factor of increased growth response alone is considered. Exact figures for cost of steaming are difficult to determine but appear to be on the order of $25-$30 for a 500 ft² bench or bed. For the same bed, the cost of ethazol is approximately $11. From these estimates a cost of 8¢/ft² for the combined treatment is reasonable. In the experiments reported in this article, costs were reimbursed through increased number of flowers within 2 or 3 wk of the onset of cut in the first crop. In the case of grower number I (Table 1), the cost of treatments with steam and ethazol was recovered before flowers in the other treatments were mature enough for cutting; indeed, 500 flowers per bench were cut before production began in the other treatments. The income from this is more than adequate to cover the cost of treatment.

Other benefits from combining steam and fungicide treatments, besides those considered above, may be mentioned also. Steaming eradicates the pathogen *Fusarium roseum* from greenhouse benches and/or beds. However, this pathogen may be disseminated with propagative material. After steaming and just before transplanting cuttings which may be contaminated with *F. roseum*, it is possible to use to advantage a combination of fungicides, sold under the commercial name of Banrot®, which includes not only ethazol but a thiophanate as well. The thiophanate is effective in control of Fusarium stem rot (induced by *F. roseum)* thus providing "insurance" against losses due to this pathogen. We have used Banrot® at the rate of 32 oz/1000 ft² and have obtained an increased growth response comparable to that achieved with ethazol alone; however, no increase in flower production was noticed with the thiophanate alone (see grower numbers II and III, Table 1). It must be emphasized here that ethazol should be applied after steaming since it is destroyed at high temperatures. It is also quite insoluble and, when applied before transplanting, was usually raked into the surface few inches of the soil so as to provide early protection for the roots of young plants.

In contrast, ridomyl is highly soluble. The variable results obtained with ridomyl could be explained as due to this variable. Increased growth was observed when ridomyl was applied to ground beds (growers II, III) but not in raised benches where the fungicide could be readily leached from the soil (grower V, Table 1).

The results reported here are preliminary in nature but suggest that application of appropriate fungicides after steaming is cost-effective and provides numerous benefits besides those associated with conventional control of soil-borne plant pathogens. Unquestionably, application of ethazol, and perhaps ridomyl in certain situations, at transplanting increases flower production. The benefit of respective applications during the conventional 2-yr culture of carnations and the frequency vs cost-effectiveness of these applications is now under investigation.

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