SOIL FUMIGATION

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SUMMARY

Soil fumigation has been practised for many years, largely for disease control. New chemicals now available are also effective killers of all problem weeds and of nearly all weed seeds in the soil, so that weed control in specialised areas has been revolutionised. Fumigation is an ideal method for weed control in home gardens where weeds like oxalis exist or in gardens or nurseries where the growing of plants from small seeds is undertaken. Small-scale trials using the particular fumigant and plant species may be desirable before large-scale activities are carried out.

INTRODUCTION

Even 80 years ago there were thousands of acres in France fumigated for the control of soil-borne disease in grape growing areas, and hundreds of tons of fumigant were used annually (1). Since then soil fumigation has been used in varying degrees for many special crops, but it has usually been regarded as a rather expensive, though usually effective method for getting rid of soil-borne diseases and pests. With the realisation of the damage caused to many crops by nematodes this work assumed a greater importance in many places.

During the last few years, however, there has been a change in the role of fumigation in many cases. The advent of new fumigants, new machines for application, and new materials such as plastic sheets, has revolutionised soil fumigation and extended its use until it is now an important technique for weed control. This weed control aspect is of tremendous significance because the effective fumigants to be discussed later not only kill all weeds present in the ground but also kill nearly all of the millions of weed seeds which are present in most acres of soil (2).

This killing of buried weed seeds has a far reaching effect, because once this population is killed the number of weeds in an area will be limited to those grown from seeds subsequently introduced. From a practical viewpoint then, one treatment with a suitable fumigant will often give satisfactory weed control of the treated area for two or more seasons, and this fact must be taken into account when considering the economics of soil fumigation. The only seeds that we find difficult to kill by fumigation are those of pasture legumes such as clovers (*Trifolium* spp.) and lotus (*Lotus* spp.) as well as those of plants such as mallows (*Malva* spp.). None of these plants are serious weeds to most people, but at Grasslands Division seeds of pasture legumes may cause serious trouble in trial work; therefore their control would be desirable. Thus if we plan to sow plots of one variety of red clover, seeds of any other red clover in the soil can cause real trouble. However, from work done to date it is clear that this problem of killing resistant seeds is by no means solved.

FUMIGATION EFFECTS

Apart from the killing of weeds and most weed seeds, all the main fumigants are toxic to fungi, bacteria, insects, and weeds, though some are more toxic to certain aspects than to others. This clean-up of the soil is not usually as complete as that from good steaming, but is usually adequate for all practical purposes (3).

(a) Biological Effects

- (1) Earthworms are killed but soon return from surrounding soil.
- (2) Nematodes. Most nematodes are effectively controlled by fumigation,

but the cyst stage of certain species as well as the eggs are the hardest to kill and may cause trouble after treatment.

(3) Bacteria. Non-spore formers such as nitrogen fixers, nitrate and nitrate formers are destroyed and nitrification inhibited, while spore formers such as ammonifiers escape treatment and multiply rapidly.

(4) Viruses. Some diseases caused by soil viruses such as "big vein" in lettuce can be controlled by certain fumigants (1).

(5) Fungi. Those with spores or sclerotia are harder to kill than others. Sometimes fumigated soil may be recontaminated with a parasite or disease that flourishes and does more harm than in an untreated soil. Both *Pythium* and *Verticillium* may act in this way.

Sometimes fumigation for weed control may destroy beneficial organisms such as the *Rhizobium* of legume nodules, or the mycorrhizas that benefit heaths, conifers, etc., and reinoculation may be necessary before satisfactory seedling growth will result (4). In this case small test plantings would be desirable before undertaking large-scale operations.

(b) Chemical effects

Some fumigants may cause changes in soil chemicals or leave residues that may affect plants or organisms. Thus under some conditions soluble chlorides or bromides may increase sufficiently to affect sensitive plants if planted too soon after treatment. It is advisable to leave treated soil for a few weeks before use, then if possible test plant using the species to be used later.

CHEMICAL FUMIGANTS

Carbon disulphide: During the latter part of last century carbon disulphide was the fumigant that was so important for the control of *Phylloxera* disease of grape growing areas in France, and by 1895 about 150,000 acres of vineyards were treated (1). Soon afterward the urgency for fumigation declined with the introduction of *Phylloxera*-resistant rootstocks, but up until 1945 carbon disulphide was still the most widely used of all soil fumigants (5).

Chloropicrin: After World War I it was found that the large stocks of chloropicrin stored in many countries could be used effectively for fumigation. It was proved to be more efficient than carbon disulphide as a space fumigant (6) and large quantities were used for this purpose. When the Hawaiian pineapple industry was threatened by soil nematodes, chloropicrin was found to be very effective in restoring yields because of nematode control (7). The use of this fumigant is still standard practice in most New Zealand glasshouse soils, but the accent is on disease control. Jacks (8) showed that neither chloropicrin nor any other chemical he tested was as efficient as steam for killing weed seeds, but of those tested chloropicrin was best. This fumigant is usually injected into the soil and the surface covered by a gas proof cover.

DD (Dichloropropene + Dichloropropane)

This mixture has been proved very effective for nematode control, but no better than chloropicrin for weed-seed control. In some of our trials weed-seed kill has been good close to the site of injection, but for general weed control it cannot compare in efficiency with the newer chemicals.

SMDC

This is a liquid which can be watered into the soil, where it hydrolyses to form a toxic vapour that effects the fumigation. The soil must be saturated sufficiently to carry the SMDC to the required depth, and if the soil surface has been reasonably smooth, the water also forms a surface seal sufficient to entrap the toxic vapour. At times the soil surface may seal to cause run-off before the soil is sufficiently saturated and deep-seated weeds such as some oxalis bulbs (*Oxalis latifolia*) may survive and require later spot treatment.

For spot treatments liquid fumigants such as this are useful. One simple method is to dibble a hole beside a surviving plant, fill the hole with dilute fumigant, cover with soil, and seal with foot pressure.

SMDC, and similar fumigants that require only a watering-can for application, are eminently suited for home use. For treating larger areas a proportioning injection attachment to a hose or irrigation system can be very useful.

ALLYL ALCOHOL

This liquid shows considerable promise as a soil fumigant. Its weed control and weed-seed kill seem to be as complete as other fumigants and its low volatility allows it to be simply watered on to the soil and water sealed.

DMTT

This is normally used as a fine white powder, but it may be in granular form. It can be used by applying to the soil, mixing by cultivation, then watering; or by dissolving the powder in water and then using in a similar manner to SMDC.

As with SMDC this fumigant is very suitable for both home garden and large-scale application. Crops can be sown about three weeks after treatment and weed control is quite satisfactory.

MB

This is perhaps the most efficient space fumigant in use today and is also very effective for the control of weeds, as being a gas it penetrates readily to considerable depths in open soil. MB is stored as a liquid either in pressure cylinders or under pressure in 1 lb sealed cans, and care must be taken in its use. No cans must ever be opened without the special applicators which puncture the cans and lead the fumigant away through a plastic tube. As used for soil fumigation from 1 lb cans, MB contains a small percentage of chloropicrin as a warning agent. Soil to be fumigated must be completely sealed with a plastic sheet, and usually any failure to achieve an effective weed kill is due to escape of gas from the sheet. Plastic sheets can now be obtained in large sizes so that a considerable area can be treated at one time. Ample soil moisture is essential to enable a good kill of weed seeds to be obtained.

For rapid action MB can be vaporised by hot water instead of by atmospheric temperature, and by this means treatment times can be greatly reduced without any loss in efficiency. After removal of the plastic sheet the gas dissipates from the soil so rapidly that most seeds or plants can safely be set within a day or two of treatment. Some people even treat soil in the morning and use it in the afternoon, but this is not recommended as a general practice.

Though MB requires a plastic sheet (say 24 ft × 6 ft) and a special applicator, many householders are finding the purchase of these worth while in view of the conveniences and efficiency of this fumigant. On some soils the fact that there is no need to saturate the soil for treatment is a distinct advantage.

COST AND EFFICIENCY

As so many present-day fumigants are efficient for weed control, they should be purchased with regard to the cost of treatment per 100 sq. ft. of soil, as well as for the convenience of method of application.

Regarding cost of treatment, trials and experience at the Grasslands Division all indicate that the dosage rates recommended by manufacturers are on the ample side. This is perhaps understandable in that they are allowing for poor application technique or unfavourable conditions, but we have found results with all fumigants tested to be as complete at half the recommended rate as at the full rate or even at double rate. We have found, too, that for seeds such as legumes that are partially resistant to treatment the kill is not improved by increasing the dosage to even four times the normal rate.

SOIL TEMPERATURE

All manufacturers of fumigants warn against their use when soil temperatures are low (some say not below 60 degrees F, some not below

Left: Untreated soil. Right: SMDC at 1 pint per 100 lbs. of soil. The photograph was taken two months after treatment. (See Manuscript paper.)

50 degrees F), but our trials indicate that even when temperatures are as low as 40 degrees F the weed control is quite satisfactory.

Thus in a trial carried out in late June 1959, seeds were buried in nylon bags, treated, then left two weeks before being recovered and sent for germination tests. The results are shown in Table 1.

TABLE 1—GERMINATION PER CENT OF SEEDS TREATED 29/6/59.
(SOIL TEMP. APPROX. 40 DEGREES F)
(Mean of two replications)

	Buried untreated	SMDC	MB	Allyl alcohol	D-D	DMTT
Red clover†	92	1	3	2	2	1
White clover	98	3	3	5	6	9
Lotus	90	79	77	78	69	71
Ryegrass	81	—	—	—	—/12*	—
Dock	60	—	—	—	—/28*	—
Nightshade	44	—	—	—	—	—
Fathen	32	—	—	—	—	—

* Replicates very different so not averaged

† Red clover (*Trifolium pratense*), white clover (*T. repens*), lotus (*Lotus uliginosus*), ryegrass (*Lolium spp.*), dock (*Rumex spp.*), nightshade (*Solanum nigrum*), fathen (*Chenopodium album*).

As seen in Table 1 the kill of grass and weed seeds was complete with the exception of the D-D treatment. Also the kill of white clover and red clover seeds was considerable, whereas the lotus seed, which was hand harvested and contained a large percentage of hard seeds, was only slightly affected. Other results of this trial but which are not shown in Table 1 are of interest. Two hundred seeds of each treatment were placed in sand, instead of on the usual pads, to germinate at the Seed-Testing Station. Germination time was 11 weeks, and if the D-D treatment is omitted only 2 of 800 red clovers germinated, no white clovers grew from 800 seeds, while for lotus the number of seeds germinated was less than one-quarter of those shown in Table 1. The differences between these results and those in Table 1 are due to the scarification received by the seeds on the pads, but not by those in the sand.

FURTHER RESULTS

One of the unexpected results found in a number of our trials has been the effect of the burial of seed on its ultimate germination. Thus in one trial to investigate the effect of doubling the rate of application of two fumigants (A and B), seeds in nylon bags were buried at 1 in. and 6 in. At each rate of chemical at each depth the results were very similar and mean results are shown in Table 2.

TABLE 2—GERMINATION PER CENT OF SEEDS TREATED 24/4/58

	Untreated	Fumigant A	Fumigant A × 2	Fumigant B	Fumigant B × 2	Buried only
White clover	78	39	47	31	39	40
Red clover	91	81	86	85	78	78
Lotus	97	71	73	79	79	82
Browntop†	79	—	—	2	1	78
Mixed weeds	9	—	—	—	—	23

† Browntop (*Agrostis tenuis*)

Table 2 shows that when the germinations of seeds from the four treatments are compared with the untreated seed, a considerable reduction has resulted from treatment. Red clover and lotus were only slightly reduced, white clover was considerably reduced, and browntop and the weeds virtually killed. However, when the treatment effects are compared

with the effects of burial without fumigation, it is seen that the clover seed germinations are very similar in each case, the burial alone having produced the same germination percentage as the burial plus fumigation. For the browntop the burial did not change the germination, while fumigation resulted in a good kill. In the case of weed seeds, fumigation killed all the seeds, while burial alone resulted in a germination percentage higher than for the untreated control. This effect was largely due to the seed of hog-cress (*Coronopus didymus*), which showed almost no germination in the seed not buried and over 20 per cent germination after burial alone. Work is continuing at the Grasslands Division on the effects of the soil on seed germination.

CONCLUSION

The advent of new chemicals and new materials in recent years has opened a new era in weed control. All the main soil fumigants today are very effective for the control of problem weeds and also kill nearly all weed seeds apart from those of some of the pasture legumes. Methods of application are relatively simple and even untrained personnel can use most fumigants with safety.

References

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