Ear Malformation in Winter Wheat after Soil Fumigation with Dichloropropene-dichloropropane Mixtures

By G. Lebbink
Institute for Soil Fertility,
Haren (Gr.),
The Netherlands

FIGURE 1. *Malformation ranged from absence of the tip to nearly complete absence of the ear.*

INTRODUCTION

Soon after the introduction of soil fumigation in The Netherlands where winter wheat is grown in the potato crop rotation scheme, the first cases of ear malformation were noted (Hijink, 1969). The rapid increase of soil fumigation in these regions has subsequently resulted in many reports of ear malformation. This side-effect of fumigation may lead to considerable yield reductions, sometimes up to more than 20%. The fact that occasionally ear malformation was seen in the second and third year after fumigation pointed to a rather persistent factor remaining in the soil.

The symptoms are most clearly visible at the stage of appearance of the ears. The malformation ranges from the absence of the tip to a nearly complete absence of the ear (Figure 1, 2, 3 and 4). Normal and malformed ears can be found on the same plant. This indicates a nonhomogeneous distribution of the causing factor in the soil.

Much research has already been performed on the cause of this ear malformation. De Clerque and D'Herde (1971) attributed the ear malformation to damage by thrips *(Limothrips cerealium)*. This insect seemed to prefer cereals grown on fumigated fields. Symptoms of thrips damage are different from the symptoms described above. Later, research by D'Herde (1974) indicated a chemical was the cause of ear malformation. Chloroallyl alcohol, possibly formed by hydrolysis of 1,3-dichloropropene, was thought to be rather persistent and responsible for the ear malformation. However, in degradation studies of 1,3-dichloropropenes in the soil, Van Dijk (1974), found a rapid biodegradation of the chloroallyl alcohols.

Field studies, carried out in The Netherlands revealed that ear malformation is not confined to one soil type. Most varieties of winter wheat seemed sensitive, although not to the same extent. In general, factors which prohibit a rapid disappearance of the

fumigant from the soil favor the occurrence of ear malformation. Such factors are low temperature, high moisture content of the soil, superficial compaction of the soil after fumigation, slaking and adsorption (Leistra, 1972). The real cause of the ear malformation however remained unexplained.

1974 Experiments

After pot experiments in 1973 failed to exhibit ear malformation, field studies with the very sensitive winter wheat variety "Manella" were undertaken. From injection at successive stages of growth it was found that the most sensitive stage is that of maximum stooling, i.e., stage 5 according to the Feekes-scale (Large, 1954). Beyond this stage no ear malformation could be induced.

Injection procedure. The chemical was injected in the sandy soil at a depth of 18 cm, between the rows of the winter wheat (16 injections per m^2). After injection, the soil was pressed by foot to avoid too rapid volatilization. Injection was carried out in March 1974 when the wheat was in the stooling stage. The products and chemicals used were: DD* soil fumigant, VIDDEN® D and TELONE® soil fumigants; pure cis- and trans-1,3-dichloropropene (bp. 105°C and 112°C resp.), 1,2-dichloropropane (bp. 95-97°C), 2,3-dichloropropene (bp. 93-95°C) and a mixture of cis- and trans-3-chloroallyl alcohol; and in addition the DD fraction with a boiling point <80°C and the fraction with a boiling point >120°C. The doses of the chemicals were so chosen that the concentration in the soil was the same as after normal autumn fumigation with DD at 250 l/ha. Hexane was added to some chemicals to obtain injectable quantities.

Results and Discussion

The numbers of malformed ears, expressed as a percentage of the total number of ears are summarized in Table 1.

Table 1 shows that 1,2-dichloropropane or a conversion product of this compound is responsible for ear malformation. The ear malformation after

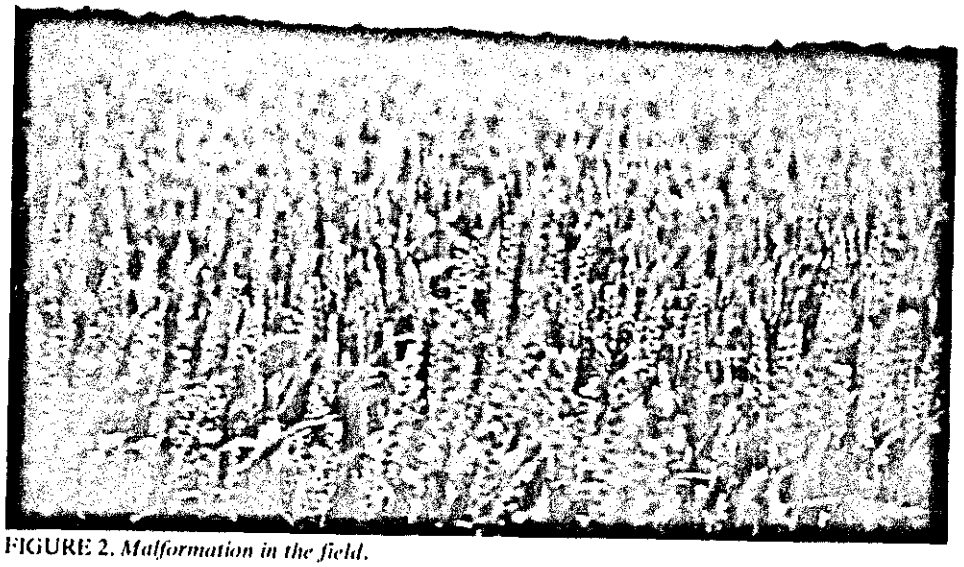

FIGURE 2. *Malformation in the field.*

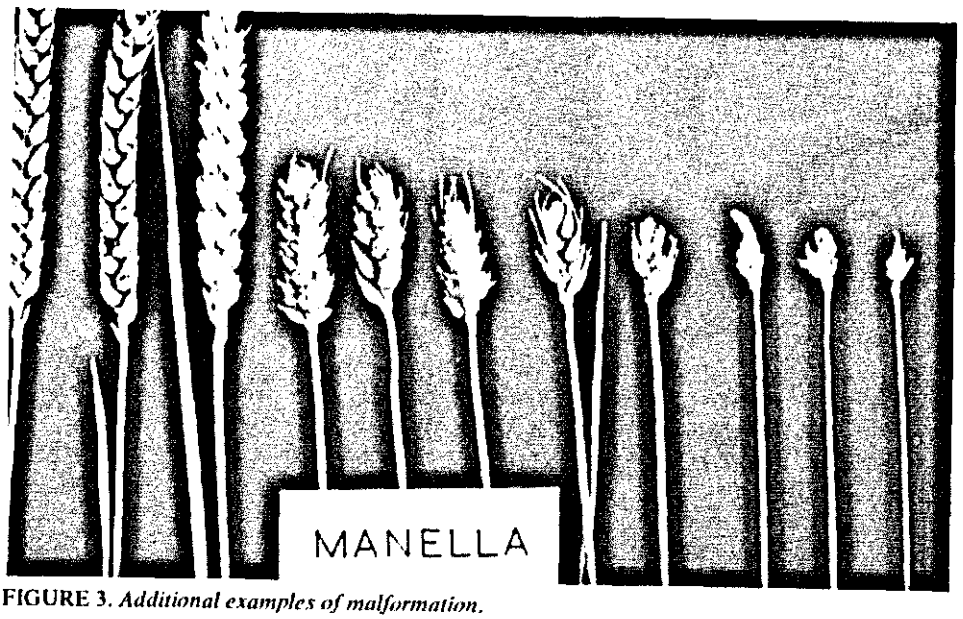

FIGURE 3. *Additional examples of malformation.*

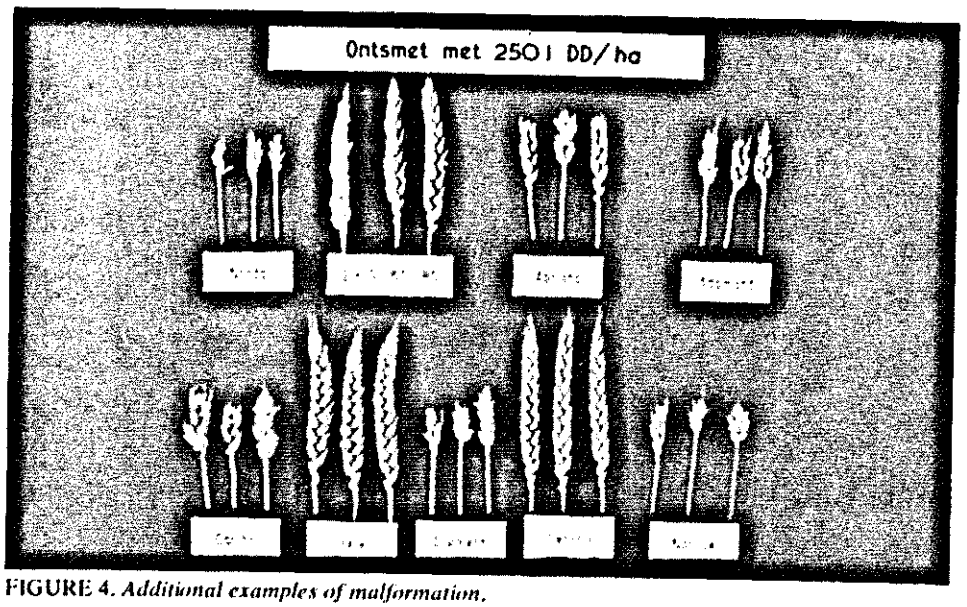

FIGURE 4. *Additional examples of malformation.*

* Trademark of the Shell Chemical Company.

application of the commercial products VIDDEN D, DD and TELONE can be explained from their content of 1,2-dichloropropane namely 25, 20 and 15%, respectively. Cis- and trans-1,3-D (as well as CAA) do not cause ear malformation. Removal of the non-nematocidal component 1,2-dichloropropane from the mixtures seems necessary to prevent the ear malformation. When manufacturing the commercial products complete removal of 1,2-dichloropropane is difficult and very expensive, however, a reduction in the level is feasible. The question thus arises to which level 1,2-dichloropropane has to be reduced to avoid ear malformation and reduction in yield.

TABLE 1. Percentage of malformed ears (m.e.) in "Manella" winter wheat after soil fumigation at the stooling stage.

Chemicals	% m.e.	Chemicals	% m.e.
Vidden D	50	2,3-D	0
DD	43	fr. bp < 80°C	0
Telone	26	fr. bp > 120°C	0
cis-1,3-D	0	CAA (67,5 l ha^{-1})	0
trans-1,3-D	2	untreated	0
1,2-D'	52		

1,3-D = 1,3-dichloropropene
2,3-D = 2,3-dichloropropene
1,2-D' = 1,2-dichloropropane
fr. bp = fraction with boiling point
CAA = chloroallyl alcohol

TABLE 2. Grain weight of normal and malformed ears.

	malformed	normal
sandy soil	44.3 mg	38.6 mg
peaty soil	43.5 mg	37.3 mg
clay soil	49.1 mg	43.9 mg

1975 Experiments

As described above, chemicals were injected in the soil in the autumn of 1974, the usual season in practice for fumigation, before sowing winter wheat. This was also done on separate plots in the spring of 1975, when winter wheat was in the stooling stage.

Treatments were as follow:

Autumn 1974: 1,2-dichloropropane at different doses, viz. 50, 25, 12.5 and 6.2 l/ha; 1,2-dichloropropane at different doses in combination with cis- and trans-1,3-dichloropropene (both 70 l/ha); DD, TELONE, and TELONE II soil fumigants in usual recommended dosages of 250, 175 and 150 l/ha, respectively.

Spring 1975: The same chemicals were used but the dosages were 25% of the autumn application. The experiments were carried out on an acid sand soil, an acid peaty sand soil and a calcarious clay soil.

Results and Discussion

The relation between percentage malformed ears and the amount of 1,2-dichloropropane at autumn and spring application is given in Figure 5. The 'no effect' level of 1,2-dichloropropane in causing ear malformation with autumn application was about 5 l/ha. With VIDDEN D, DD and TELONE about 62, 50 and 25 l/ha, respectively, of 1,2-dichloropropane were applied to the soil in autumn, so the 'no effect' level is easily exceeded. TELONE II soil fumigant, containing about 3% of 1,2-dichloropropane, caused negligible ear malformation. When applied in spring at the stooling stage the 'no effect' level of 1,2-dichloropropane is about 1 l/ha. The same percentage of malformed ears was obtained by injecting 25% of the amount used in autumn. After fumigation with DD in autumn when 2-4% of the amount of 1,2-dichloropropane is still present at the stooling stage ear malformation can be expected.

There seems to be no interaction between 1,3-dichloropropene and 1,2-dichloropropane in causing ear malformation. The relation between percentage malformed ears and grain yield in percentage of the yield of the untreated plots is given in Figure 6. When percentages of malformed ears are higher than about 15, yield reduction can be expected. As percentage of malformed ears increases above 15, the yield continues to decrease. In general a more severe ear malformation is noticed at a higher percentage of malformed ears.

At percentages of malformed ears below 15 generally no yield reduction is obtained. The average grain weight of malformed and normal ears of the three trials is given in Table 2.

From Table 2 it can be seen that the grain weight of malformed ears is

much higher than the grain weight of normal ears. At lower percentages of malformed ears the lower number of grains in the malformed ears is completely offset by a higher grain weight. The yield at low percentages of malformed ears is sometimes even higher than the yield of the untreated but this may be attributed to a positive partial sterilization effect of the 1,3-dichloropropenes.

Conclusions

1. The ear malformation is caused by 1,2-dichloropropane or a conversion product of this compound.
2. The "no effect" level of 1,2-dichloropropane is causing ear malformation in the sensitive winter wheat variety "Manella," was at autumn application (usual date of fumigation), about 5 l/ ha and at the stooling stage in spring about 1 l/ ha.
3. At percentages of malformed ears higher than about 15 yield reduction can be expected.
4. At percentages of malformed ears below 15 the lower number of grains in the malformed ears was completely offset by a higher grain weight.
5. The 1,2-dichloropropane content of the mixtures, most often used, (DD, VIDDEN D and TELONE) is so high that the "no effect" level is exceeded. As a result, in many cases yield reduction can be expected.
6. There is no interaction between 1,2-dichloropropane and 1,3-dichloropropene in causing ear malformation.
7. Reducing the content of 1,2-dichloropropane in the mixtures to a lower level (about 3%) prevents ear malformation and yield reduction. TELONE II, a recently developed soil fumigant of The Dow Chemical Company, meets these requirements.
8. The results emphasize the necessity to involve all the components of pesticide formulations in the study of their effect.

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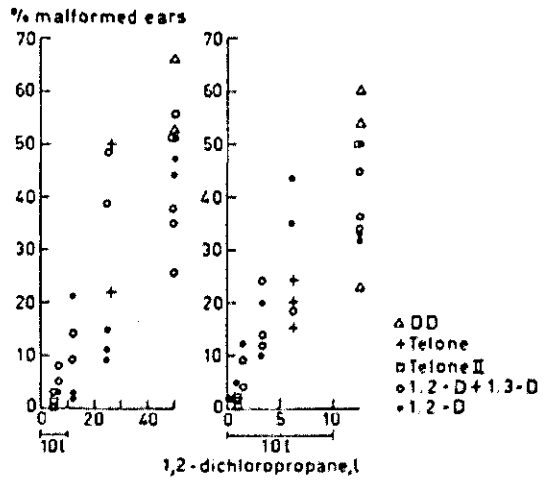

FIGURE 5. *Relationship between percentage of malformed ears and the amount of 1,2-dichloropropane at autumn and spring applications.*

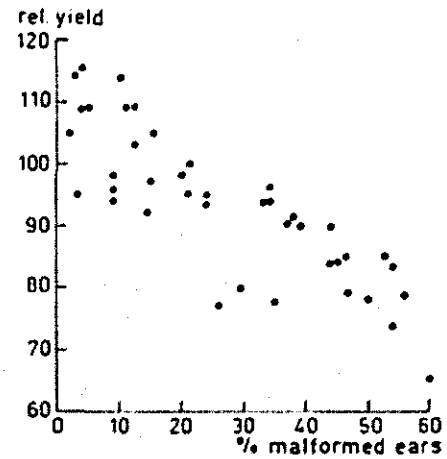

FIGURE 6. *Relationship between percentage of malformed ears and grain yield in percentage of the yield of the untreated plots.*