Med. Fac. Landbouww. Rijksuniv. Gent, 41/2, 1976

EAR MALFORMATION IN WINTER WHEAT AFTER SOIL FUMIGATION WITH DICHLOROPROPENE-DICHLOROPROPANE MIXTURES

G. LEBBINK

Institute for Soil Fertility
Haren (Gr.). The Netherlands

SUMMARY

After soil disinfection with dichloropropene-dichloropropane mixtures often ear malformation is observed in winter wheat, occasionally even in the third year after fumigation. Not all varieties are equally sensitive. It was found that the most sensitive stage is that of maximum stooling. After soil injection with the separate components of the mixture at the most sensitive stage (March/April) it was established that the phenomenon was caused by 1,2-dichloropropane or a conversion product of this component and already at a dose of 1 l.ha^{-1}. The percentage of yield decrease, however, was lower than the percentage of malformed ears, because the lower number of grains in the malformed ears is partly - or, in less severe cases, completely - offset by a high mean grain weight. There is no interaction between 1,3-dichloropropene and 1,2-dichloropropane in causing ear malformation. Lowering of the amount of 1,2-dichloropropane in the mixtures prevents yield reduction and ear malformation.

INTRODUCTION

Soon after the introduction of soil fumigation in those regions where winter wheat is in the crop rotation scheme the first cases of ear malformation were mentioned (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. The symptoms are most clearly visible at the stage of appearance of the ears. The malformation ranges from the absence of the tip till a nearly complete absence of the ear. Normal and malformed ears can be found on the same plant. This indicates a non homogeneous distribution of the causing factor in the soil (Plate 1).

A fair amount of research has already performed on the cause of this ear malformation. De Clerque and D'Herde (1971) attributed the ear malformation to damage by the thrips *Limothrips cerealium*. This insect would prefer cereals on fumigated fields. Symptoms of thrips damage are different from the symptoms described above. Later research by D'Herde (1974) indicated a chemical as the cause of ear malformation. Chloroallyl alcohol, possibly, formed by hydrolysis of 1,3-dichloropropene was thought to be rather persistant and responsible for the ear malformation. In degradation studies of 1,3-dichloropropenes in the

Plate 1. Normal (left) and malformed ears (others).

soil, Van Dijk (1974), however, found a rapid biodegradation of the chloroallyl alcohols. Field studies, carried out in The Netherlands revealed that ear malformation is not committed to type of soil. 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 favour 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.

EXPERIMENTS IN 1974

After pot experiments in 1973 failed to show ear malformation we turned to field studies with the very sensitive winterwheat variety "Manella". 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). After passing this stage no ear malformation could be induced.

Injection procedure. The chemical was injected in the (sand) soil at a depth of 18 cm, between the rows of the winter wheat (sixteen shots per m^2). After injection the soil was pressed by foot to avoid rapid volatilisation.
The date of injection was March 1974 when the wheat was in stage of stooling.
The chemicals used were: commercial DD, Vidden D and Telone; 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; furthermore the DD fraction with boiling point <80°C and the fraction with boiling point >120°C. The dosis of the chemicals was so chosen that the concentration in the soil was the same as after normal autumn fumigation with 250 l DD ha^{-1}. To some chemicals hexane was added to get injectable quantities.

Results and discussion

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

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

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 1 shows that 1,2-dichloropropane or a conversion product of this compound is responsible for the ear malformation. The ear malformation after 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%, resp. Cis- and trans-1,3-D (as well as CAA) do not give 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 or at least yield reduction.

EXPERIMENTS IN 1975

As described before, chemicals were injected in the soil in the autumn of 1974, the usual season for fumigation in practice, before sowing of winter wheat. This was also done on seperate plots in spring 1975, when winter wheat was in stage of stooling.
Autumn 1974: 1,2-dichloropropane at different doses, viz. 50, 25, 12.5 and 6.2 $l.ha^{-1}$; 1,2-dichloropropane in different doses in combination with cis- and trans-1,3-dichloropropene (both 70 $l.ha^{-1}$); DD, Telone and Telone II in usual doses of 250, 175 and 150 $l.ha^{-1}$, resp.
Spring 1975: same chemicals but the doses are 25% of 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 1.
The 'no effect' level of 1,2-dichloropropane in causing ear malformation at autumn application was about 5 $l.ha^{-1}$. With Vidden D, DD and Telone about 62, 50 and 25 $l.ha^{-1}$, resp., of 1,2-dichloropropane is brought in the soil in autumn, so the 'no effect' level is easily exceeded. Telone II, containing about 3% of 1,2-dichloropropane hardly caused ear malformation.
When applied in spring at the stage of stooling the 'no effect' level of 1,2-dichloropropane is about 1 $l.ha^{-1}$. The same percentage of malformed ears was obtained by giving 25% of the amount used in autumn.
When after fumigation with DD in autumn 2-4% of the amount of 1,2-dichloropropane is still present at the stage of stooling 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 2.
At percentages of malformed ears higher than about 15, yield reduction can be expected. As percentage of malformed ears increases further, 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 in general no yield reduction is obtained.
The average grain weight of malformed and normal ears of the three trials is given in table 2.

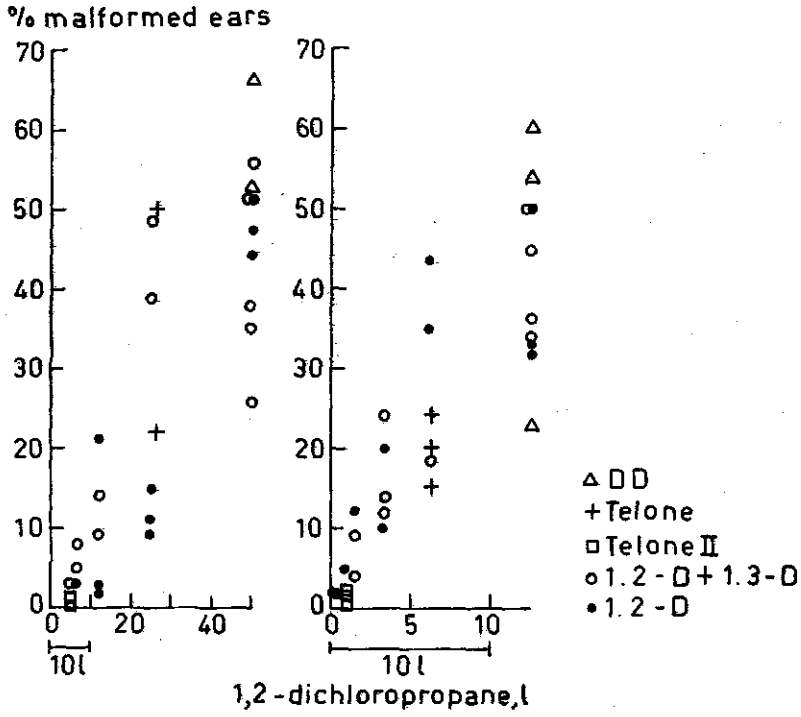

Figure 1. Relation between ear malformation and dosis 1,2-dichloropropane (1,2-D'). Left: autumn application, right: spring application.

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

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 sterilisation effect of the 1,3-dichloropropenes.

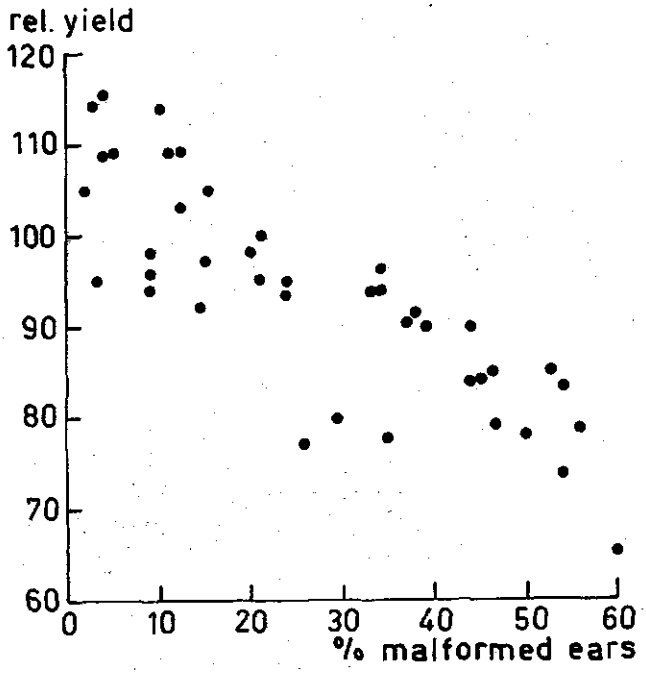

Figure 2. Effect of ear malformation on grain yield.

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 in causing ear malformation in the sensitive winter wheat variety "Manella" was at autumn application (usual date of fumigation) about 5 $l.ha^{-1}$, at the stage of stooling about 1 $l.ha^{-1}$.
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 may 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, meets these requirements.
8. The results emphasize the necessity to involve all the components of pesticide formulations in the study of their effect.

REFERENCES

De Clerq, R. and D'Herde, C.J.D. 1971. Aantasting van wintertarwe door *Limothrips cerealium* Hal. na voorafgaandelijke grondontsmetting met dichloorpropaan-dichloorpropeen. Meded. Fac. Landbouwwet., Rijksuniv. Gent, 36: 260-265.

De Clerq, R. 1974. Schade in wintertarwe na grondontsmetting met dichloorpropaan-dichloorpropeen. Landbouwtijdschrift 27: 303-311.

Van Dijk, H. 1974. Degradation of 1,3-dichloropropenes in the soil. Agro-ecosystems 1: 193-204.

Hijink, M.J. 1969. Werking en nevenwerkingen van grondontsmettingsmiddelen. Landbouwkd. Tijdschr. 81: 87-92.

Large, E.C. 1954. Growth stages in cereals. Plant Pathol. (London) 3: 128-129.

Leistra, M. 1972. Diffusion and adsorption of the nematocide 1,3-dichloropropene in soil. Doctoral thesis, Wageningen, 105 pp. *Also:* Agric. Res. Rep. (Wageningen) 769: 105 pp.