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Response of pasture grass to thionazin and other pesticides

Centre for Agricultural Publishing and Documentation

Wageningen – 1977

Abstract

Ennik, G.C. & T. Baan Hofman (1977) Response of pasture grass to thionazin and other pesticides. Agric. Res. Rep. (Versl. landbouwk. Onderz.) 867, ISBN 90 220 0641 7, (v) + 41 p., 9 figs, 15 tables, 6 refs, Eng. summary.
Also: Publ. Cent. Agrobiol. Res. 035.

Study was made of the effect of thionazin on pasture yield, in relation to time of application, water supply, nitrogen supply, yield of preceding cuts and nematode density of the soil. Other nematicides/insecticides, fungicides and growth regulators were compared. Thionazin treatment of pasture resulted in an average increase in annual yield of dry matter of 166 g/m^2; the increase was greater for old sand soil than for young reclaimed loam soil. The effect was small or negative in the first cut, but became considerable and positive as the season advanced. When applied for the first time to the later cuts the increase in yield was immediate and of normal magnitude. The effect was greater with drought than with a near optimum water supply. Similar increases were obtained with other nematicides/insecticides, but not with growth regulators. Adding fungicides to the nematicides/insecticides usually had no further effect on yield. No reliable relation was found between yield response and death of nematodes.

Free descriptors: nematicides, insecticides, fungicides, growth regulators, nematodes, sprinkler irrigation, *Lolium perenne*.

ISBN 90 220 0641 7

This publication will also be issued as Publication 035 of the Centre for Agrobiological Research (CABO), Wageningen.

Contents

1 Introduction

Both with low and high nitrogen supply, thionazin treatment produced more pasture grass than control plots (Ennik, 1972). For a better understanding of the effect its relation to time of application, water supply, yield of preceding cuts and nematode population of the soil was studied in more detail. In addition, comparative tests were made with other pesticides and some growth regulators.

2 Design and management

In all trials, thionazin (*OO*-diethyl *O*-pyrazin-2-yl phosphorothioate) was applied as Nemafos® (Cyanamid of Great Britain Limited, Gosport, Hampshire), a liquid concentrate containing 480 g active ingredient (a.i.) per litre. Measured amounts were diluted with water at 2.25 litre per m^2, sprayed on the herbage and immediately washed down with another 2.25 litre of water per m^2. The control plots received water at 4.5 litre per m^2 added in the same way. The first application was usually in April, subsequent applications, if any, 1-3 weeks after harvesting. Yield was measured by taking one swathe from the centre of each plot by motor scythe. Phosphate and potassium were amply applied once or twice a year. Nitrogen was applied in spring and immediately or a few days after harvesting. Amounts of fertilizer N refer to the control plots, because treated plots received a little more from thionazin, 110 g N per kg thionazin applied. Soil samples for nematode counts were taken with a borer 2.5 cm in diameter from the 0-5 cm layer.
The following detailed information about the separate trials is not essential to understand the results, but can be used for reference if wanted.

Trial IBS 1432 was established in 1970 to maximize grass yield by optimum growing conditions. Thionazin plots were superimposed in spring 1971.

Site: newly reclaimed polder East-Flevoland. *Soil*: loam soil (content of organic matter 40 g kg^{-1}. *Age of sward*: sown on arable in September 1968 with a mixture of 21 kg perennial ryegrass pasture type cv. Sceempter (= Semperweide) and 12 kg tetraploid perennial ryegrass hay type cv. Barvestra per hectare. *Botanical composition*: almost entirely perennial ryegrass (*Lolium perenne*). *N supply*: two levels of N, as calcium nitrate, also in the preceding year 1970. At the higher level of N of 8 to 12 g m^{-2} before each cut, N was in full supply as shown by a content of NO_3 of more than 6 g kg^{-1} in the dried grass. The lower level of 6-8 g m^{-2} was slightly suboptimal. *Thionazin supply*: 3.8 g of a.i. per m^2 for each cut. One series was treated with thionazin late in 1970 before the scheduled treatment began in spring 1971. Controls received no thionazin. *Plot size*: 10 m x 2 m, net area 12 m^2 (area minus margin). *Number of replicates*: 3. *Number of cuts*: 5. *Nematode counts*: 8 September 1971; soils samples were taken per treatment (bulked for 3 replicates; about 11 cores per replicate).

Trial IBS 1545 was established in 1972 to measure the thionazin effect on growth rates between successive cuts by sampling on regrowth. Besides the plots for regular cutting (up to Cut 4 at time intervals of 5 weeks; between Cut 4 and 5 time interval was 9 weeks), spare plots were harvested 1 or 3 weeks after regular cutting. Thereafter spare plots were not used further, but till then they had been treated as the regular cut plots, thus contributing to the number of plots from which the average yields of the regular cuttings were calculated.

Site: same field as IBS 1432. *Age of sward and botanical composition*: as IBS 1432. *N supply*: 12 g m^{-2} for each cut as calcium nitrate or ammonium nitrate limestone. *Thionazin supply*: 3.8 g a.i. per m^2 for each cut. Controls received no thionazin. *Plot size*: 5 m x 2 m, net area 5.6 m^2. *Number of replicates*: 3. *Number of cuts*: 5.

To trial IBS 1545, a small trial was added in which the thionazin effect on grass was studied with suboptimal N supply. *N supply*: 9 g m^{-2} to Cut 1, 5 g m^{-2} to following cuts. *Other data* identical with those of IBS 1545.

Trial IBS 1546 was established in 1972 to investigate the effect of thionazin on the next cut if the first treatment was before the 1st, 2nd, 3rd or 4th cut. Until treatment, management of these plots was similar to that of control plots. Application of thionazin was not repeated except for the plots treated before Cut 1, which were treated again before Cut 2.

Site: same field als IBS 1432. *N supply* 11.6 g m^{-2} for each cut. *Thionazin supply*: one single supply of 3.8 g of a.i. per m^2 to concerning cut (plots treated before Cut 1 were also treated before Cut 2). *Nematode counts*: 8 December 1972; soil samples (20 cores from each plot) were taken from each replicate of control, 'thionazin to Cut 2' and 'thionazin to Cut 4'. *Other data* identical with those of IBS 1545.

Trial IBS 1547 was established in 1972 to compare the effect of thionazin on grass yield with that of some growth regulators and compounds which may have a similar effect. Each compound was applied at two dosages (Table 1). Treatments were repeated after each cut unless visible damage to grass was seen. If so, the compound was not applied or the dosage reduced.

Table 1. Treatments in Trial IBS 1547. Values are mass of active ingredient per unit area (mg m^{-2}).

Common name	Synonym or trade name	Rate	Cut				
			1	2	3	4	5
TIBA	TIBA	low	10	10	10	10	10
	(pure)	high	35	35	35	35	35
Ethephon	Ethrel	low	48	48	34	34	34
	(480 g l^{-1} a.i.)	high	192	0	69	69	69
Daminozide	B-9	low	200	200	200	200	200
	(pure)	high	800	800	1200	1200	1000
6-azauracil	Azauracil	low	100	0	29	29	11
	(pure)	high	200	0	57	57	23
Chlorflurecol-methyl	CF 125	low	13	13	11	11	7
	(125 g l^{-1} a.i.)	high	100	0	32	32	29
Chlormequat	CCC	low	144	144	144	144	144
	(360 g l^{-1} a.i.)	high	288	216	216	216	216
DNOC	DNOC	low	480	480	179	0	71
	(500 g l^{-1} a.i.)	high	960	0	357	0	143
Malathion	Malathion	low	50	50	50	50	50
	(500 g l^{-1} a.i.)	high	200	200	200	200	200
Thionazin	Nemafos	low	1920	1920	1920	1920	1920
	(480 g l^{-1} a.i.)	high	3840	3840	3840	3840	3840

Thionazin was applied in 2 litre of water per m^2 and washed down with another 2 litre per m^2. Before Cut 1, chlormequat was diluted with 4 litre of water per m^2 and sprayed on the herbage, the other compounds and chlormequat in Cuts 2-5 were diluted in water at 0.06 litre per m^2, to which 0.25 ml/litre Citowett was added and sprayed under pressure 0.2 MPa. Of the control plots, one series was supplied with tapwater at 4 litre per m^2 and the other series with 0.06 litre per m^2.

Site: same field as IBS 1432. *Age of sward and botanical composition*: as IBS 1432. *N supply*: 11.3 g m^{-2} for each cut as calcium nitrate or ammonium nitrate limestone. *Plot size*: 5 m x 2 m, net area 5.6 m^2. *Number of replicates*: 3; two control series of 3 replicates each. *Number of cuts*: 5. *Nematode counts*: 8 December 1972; soil samples (20 cores per plot) were taken from each replicate of 'thionazin low dosage', 'thionazin high dosage', 'control with little water'.

Trial IBS 1630 was established in 1973 to compare the effect of thionazin on grass yield with that of many other nematicides/insecticides and a few fungicides as listed in Table 5. The first application was in April; treatments were repeated after Cuts 1-3. The solid compounds were mixed with some sand and broadcast, the liquid compounds (including thionazin) were diluted with 0.06 litre of water per m^2 and sprayed on the foliage under pressure. After all compounds had been applied, they were washed down by sprinkling for 1 h (about 6 litres of water per m^2). At the second and later applications, the fungicides benomyl and prothiocarb were sprayed after the other compounds had been washed down. At the third and fourth application, thionazin was applied as described in the beginning of this Section, thus being washed down before it had dried up on the foliage. Drying up on the leaves before washing down, as in Cut 1 and 2, seemed to increase the damage by thionazin to the grass.

Site: same field as IBS 1432. *Age of sward and botanical composition*: as IBS 1432. *N supply*: 12.8 g m^{-2} for each cut as combined NPK fertilizer or as calcium nitrate. *Plot size*: 2 m x 5 m, net area 5.6 m^2. *Number of replicates*: 3; three control series of 3 replicates each. *Number of cuts*: 5. *Nematode counts*: 4 September 1973: soil samples of 'Control Series 1', and 12 October 1973: soil samples per treatment (bulked from 3 replicates; 11 cores from each replicate) were taken.

Trial IBS 1631 was established in 1973 to investigate whether there was any relation between the effect of thionazin on yield and the water supply of the grass. Therefore part of the trial was irrigated by sprinkling during spells of drought. Treatments were all possible combinations of 3 nitrogen levels, with or without thionazin, with or without sprinkler irrigation. For technical reasons, the irrigated plots were grouped together, in spite of excluding the possibility of a statistical analysis of the interaction between thionazin effect and water supply. No extra water was supplied to Cut 1. Irrigation was provided 4 times to Cut 2, 3 times to Cut 3, 5 times to Cut 4, once to Cut 5.

Site: same field as IBS 1432. *Age of sward and botanical composition*: as IBS 1432. *N supply*: 2.1, 8.6 or 12.4 g m^{-2} for each cut as combined NPK fertilizer or as calcium nitrate. *Thionazin supply*: 2.9 g of a.i. per m^2 for each cut to Cuts 1-4. Method of application was the same as in IBS 1630: before Cut 1 and 2, grass was sprayed with thionazin in little water, which was washed down after a short time; before Cut 3 and 4, grass was sprayed with thionazin in much water and washed down immediately. *Plot size*: 2 m x 5 m, net area 5.6 m^2. *Number of replicates*: 3. *Number of cuts*: 5. *Nematode counts*: 4 September 1973; soil samples from each treatment (bulked from 3 replicates) were taken from controls with and without sprinkler irrigation.

Trial IBS 1632 was established in 1973 for an analysis of the relation between the thionazin effect on yield and the density of the sward to answer the question whether a positive effect of thionazin on yield occurred only in an 'open' sward or also if the sward were fully closed. Differences in sward density were obtained by initiating N dressings at different times of the season before subsequent regrowth, none being applied earlier. Where large dressings with nitrogen continued for longer time, sward density diminished and the sward became more open. Two N levels were included. Till Cut 3 inclusive, thionazin was only applied to the plots dressed with N. In later cuts, application of thionazin was restricted to a single treatment before Cut 4 of the plots, dressed with N for the first time before Cut 4 or 5 (Table 2).

Site: same field as IBS 1432. *Age of sward and botanical composition*: as IBS 1432. *N supply*: two N levels: 8.4 and 12.0 g m^{-2} for each cut if fertilized; N was given as combined NPK fertilizer. *Thionazin supply*: 2.9 g of a.i. per m^2 for each cut if applied. Method of application was the same as in IBS 1630. *Plot size*: 2 m x 5 m, net area 5.6 m^2. *Number of replicates*: 3. *Number of cuts*: 5. *Nematode counts*: 4 September 1973; soil samples from each treatment (bulked from 3 replicates) were taken from control and 'thionazin to Cuts 1 to 3' at the highest N level.

Trial IBS 1633 was established in 1973 to investigate the effect of thionazin and some other nematicides/insecticides on the yield of an old pasture. The compounds used are listed in Table 7. The appropriate amounts (except for thionazin, see below) were mixed with sand, sown on the plots, and washed down with water at 4.5 litre per m^2. Treatment was repeated before Cut 2 and 3.

Site: sand soil north of Wageningen. *Age of sward*: about 15 years. *Botanical composition*: perennial ryegrass and some other grasses and herbs. *N supply*: 11.9 g m^{-2} for each cut as combined NPK fertilizer or ammonium nitrate limestone. *Thionazin supply*: 2.9 g of a.i. per m^2 for each cut (except Cut 4) as described in the beginning of this Section. *Plot size*: 2 m x 5 m, net area 5.0 m^2. *Number of replicates*: 3; 2 control series of 3 replicates each. *Number of cuts*: 4. *Nematode counts*: some weeks before Cut 1 and immediately after each cutting, samples were taken of the treatments 'Control Series 1', oxamyl and fenamiphos, and after Cut 4 of all treatments (bulked from 3 replicates). Soil samples for examination for other soil animals were taken from the 0-5 cm layer of both control series on 14 November 1973.

Trials IBS 1709, 1710 and 1711 were established in 1974 to compare the effect of thionazin with that of aldicarb and fensulfothion and in particular to test the effect of adding a fungicide treatment to each of the nematicides/insecticides. Treatments and application rates are presented in Table 8. Thionazin was applied as described at the beginning of this Section. The granules of aldicarb and fensulfothion were soaked in water for one day before application (required amount of pesticide for 10 m^2 in 10 litres of water) and the extract was sprayed on the plots in the same way as thionazin. The fungicides were sprayed on the herbage after washing down the nematicides, except for Cut 3 in 1974 of IBS 1711 to which the fungicides were applied before washing down the other pesticides. The trials were continued on the same plots in 1975.

IBS 1709. Site: sand soil north of Wageningen (same farm as IBS 1633). *Age of sward:* old pasture, but in 1972 resown after rotavating. *Botanical composition*: mainly perennial ryegrass. *N supply*: in 1974 11.9 and in 1975 12.5 g m^{-2} for each cut. *Pesticide supply*: nematicides/insecticides in 1974 to Cuts 1, 2 and 3, in 1975 to Cut 1 only; fungicides in 1974 to Cuts 1, 2, 3 and 4, in 1975 to Cuts 1, 2 and 4. *Plot size*: 2 m x 5 m, net area 5.0 m^2. *Number of replicates*: 3; 3 control series of 3 replicates each. *Number of cuts:* 4, both in 1974 and 1975. *Nematode counts*: 21 October 1974 and 2 October 1975.

IBS 1710. Site: sand soil north of Wageningen (different site from IBS 1633 and 1709). Sensitive to drought. *Age of sward*: sown to pasture after deep-ploughing (1 m) some years before start of trial. *Botanical composition*: perennial ryegrass and some other grasses and herbs. *N supply*: in 1974 11.9 and in 1975 12.2 g m^{-2} for each cut. *Pesticide supply*: in 1974 to Cuts 1, 2 and 3; in 1975, nematicides/insecticides to Cut 1 only, fungicides to Cuts 1, 2 and 3. *Plot size*: 2 m x 5 m, net area 5.6 m^2. *Number of replicates and cuts*: as IBS 1709. The field was grazed early in spring 1974 before starting the trial. *Nematode counts*: 22 October 1974 and 11 November 1975.

IBS 1711. Site: loam soil in new reclaimed polder East Flevoland (different site from IBS 1432). *Age of sward*: sown in August 1973 after arable land. *Botanical composition*: perennial ryegrass pasture type cv. Pelo. *N supply*: 13.1 g m^{-2} for each cut both in 1974 and 1975. *Pesticide supply*: in 1974 to Cuts 1, 2, 3 and 4; in 1975, nematicides/insecticides to Cut 1 only, fungicides to Cuts 1, 2 and 4. *Plot size*: as IBS 1710. *Number of replicates*: as IBS 1709. *Number of cuts*: 5 in 1974; 4 in 1975. *Nematode counts*: 17 October 1974 and 8 October 1975.

3 Results

3.1 EFFECT ON YIELD

In previous studies (Ennik, 1972), the effect of thionazin on yield of the first cut was often absent or slightly negative. This was confirmed by the results of trials in 1971 and 1972 (Fig. 1A and B). When applied for the first time to the later cuts of a sward heavily dressed with N, either from the beginning of the season (Figs. 1A (below) and 2A) or concurrent with thionazin treatment (Fig. 3), the yield increased immediately in response to thionazin treatment. This indicates that a previous depressive effect of thionazin or a preceding heavy cut were not essential. As shown by Figure 2, fresh weight responded earlier to thionazin than dry weight. In some other trials, such a difference in reaction rate did not occur.

Figure 3 shows that yields declined more as repeated high N applications commenced earlier. The thionazin effect, however, seemed rather independent of yield and sward density. Statistical analysis produced no significant interaction (except for Cut 3) between the effect of thionazin on yield and time at which N application began or (except for Cut 3) between the effect of thionazin and the amount of applied N (Table 2). The thionazin effect on Cut 1 and 2 may have been affected by method of application (see Section 2, Trial IBS 1630) that caused some leaf burn.

During dry spells in 1973, yield considerably increased with sprinkler irrigation (Fig. 4 and Table 3). Details on water supply are given in Section 2 (Trial IBS 1631). After Cut 2, thionazin had increased yield, and more so when the soil was dry than when irrigated (again the effect at Cut 1 and 2 may have been affected by the other method of application of thionazin). There was no significant interaction between effect of N supply and thionazin on yield.

In one experiment the growth rate of a perennial ryegrass sward was estimated by sampling on regrowth between regular cuttings (Fig. 5). The results indicate that thionazin, if effect on yield was positive, usually increased growth rate after cutting until closure of the canopy, which is normally attained at 150 g dry matter per square metre (Alberda, 1968). Thereafter growth rate was either the same (third period), or faster on the thionazin plots (fourth and fifth period) which may have been caused by increased net photosynthesis or reduced losses of plant material, e.g. by parasites or decomposing organisms.

Since fresh yield and number of tillers increase in proportion (Ennik, 1972), it was suggested whether thionazin may activate originally dormant buds. To investigate this, the effect of thionazin was compared with that of several growth regulators or compounds which may break dormancy. Table 4 shows that only thionazin increased yield.

In several other trials, thionazin was compared with other pesticides. The rather

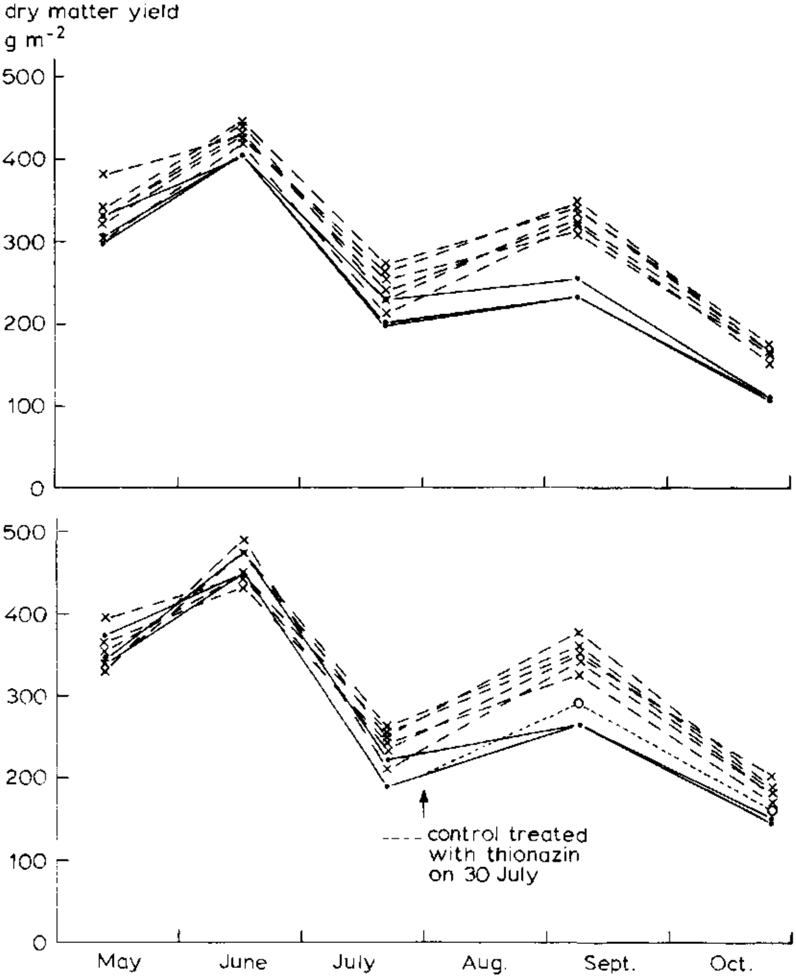

Figure 1A. IBS 1432. Effect of thionazin, applied before each cut, on yield of 5 successive cuts in 1971 with fertilizer N suboptimal, 6-8 g m^{-2} per cut (above) or adequate, 8-12 g m^{-2} per cut (below). One control plot with adequate N was erroneously treated with thionazin on 30 July. Solid lines: control plots, dashed lines: thionazin treated plots.

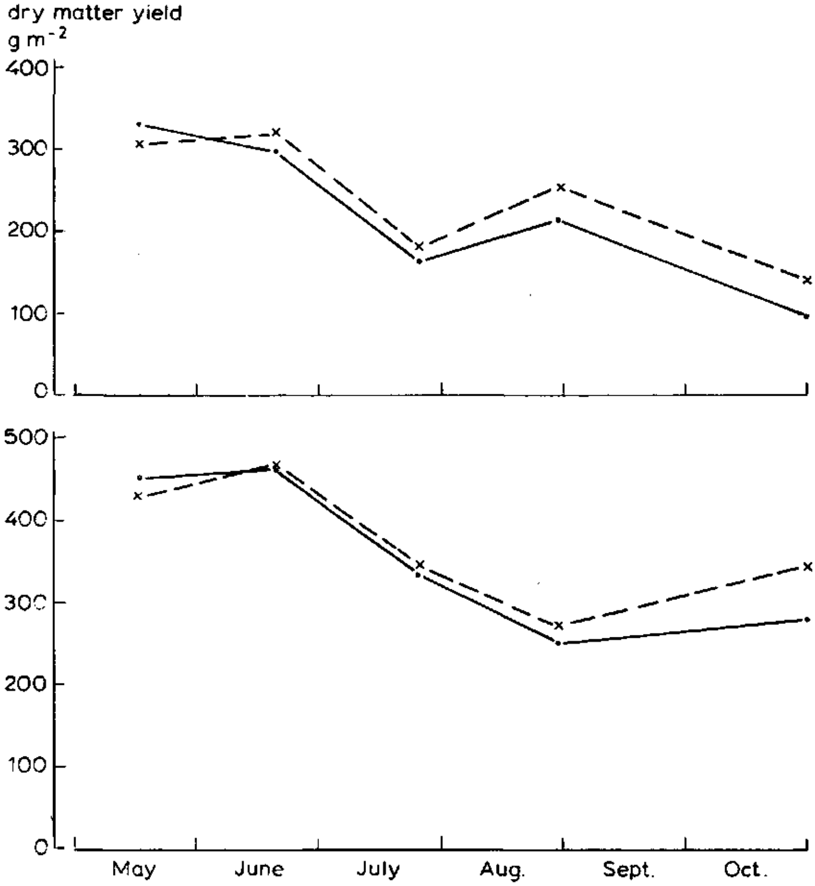

Figure 1B. IBS 1545. Effect of thionazin, applied before each cut, on yield of successive cuts in 1972 with fertilizer N suboptimal, 1st cut: 9 g m^{-2}, next cuts: 5 g m^{-2} per cut (above) or adequate, 12 g m^{-2} per cut (below). Averages of at least 3 replicates. Solid lines: control plots, dashed lines: thionazin treated plots.

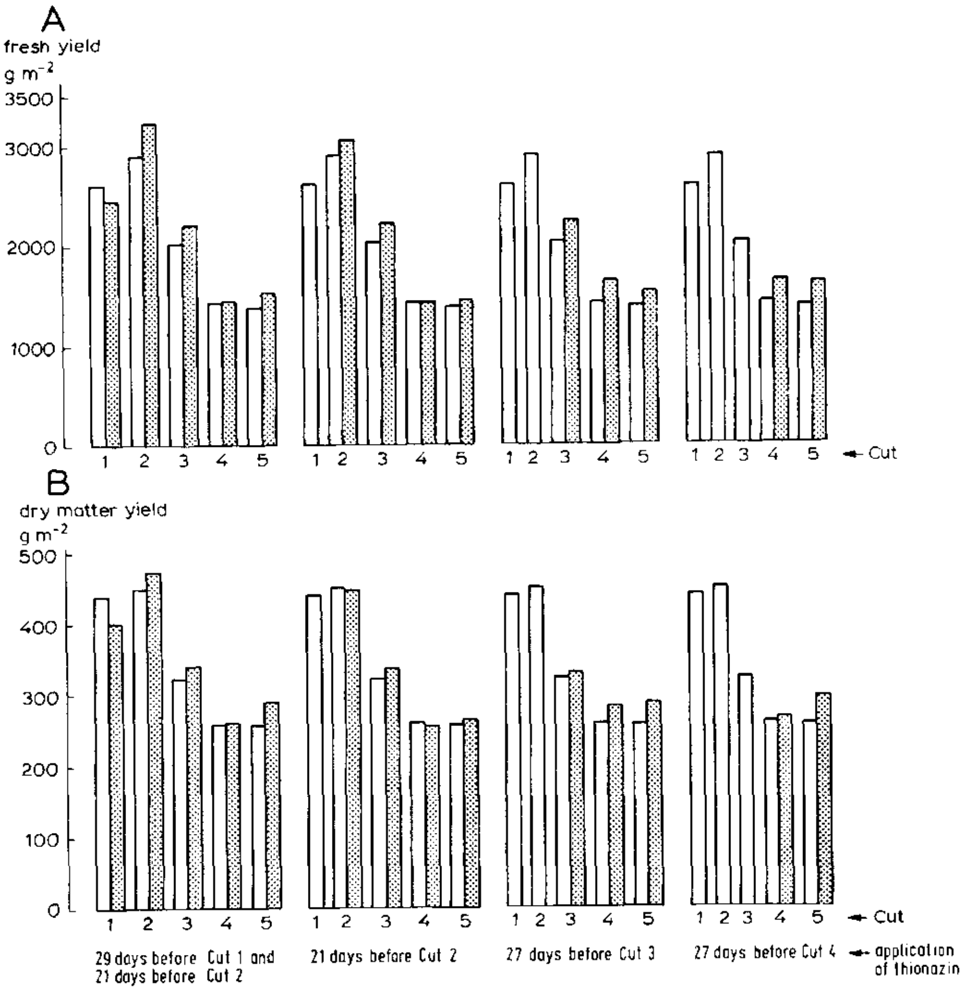

Figure 2. IBS 1546. Effect of thionazin, applied at different times, on yield of grass with high N supply during the whole season in 1972. Dates of cutting: Cut 1 1972-05-16, Cut 2 1972-06-20, Cut 3 1972-07-25, Cut 4 1972-08-29, Cut 5 1972-10-31. Unshaded: control plots, shaded: thionazin treated plots. A. Fresh yield. B. Dry matter yield.

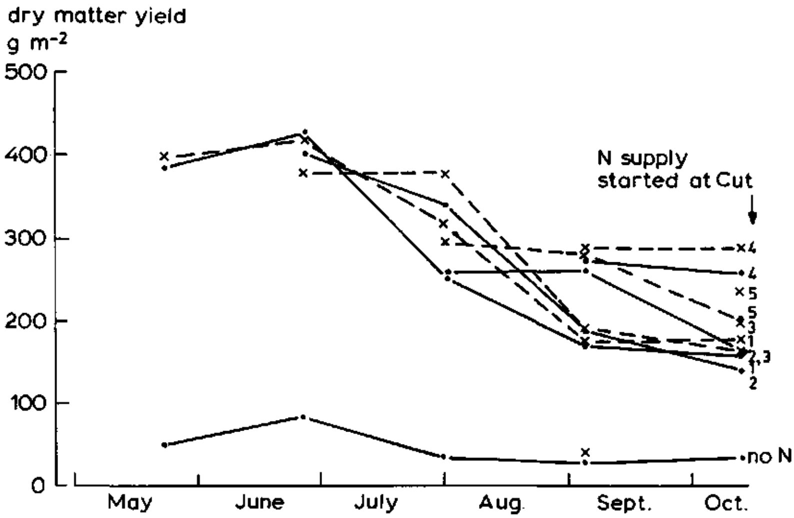

Figure 3. IBS 1632. Effect of thionazin, whose application was started at the same time as N (12 g m^{-2} per cut), on yield in 1973. Solid lines and dots: control plots, dashed lines and crosses: thionazin treated plots.

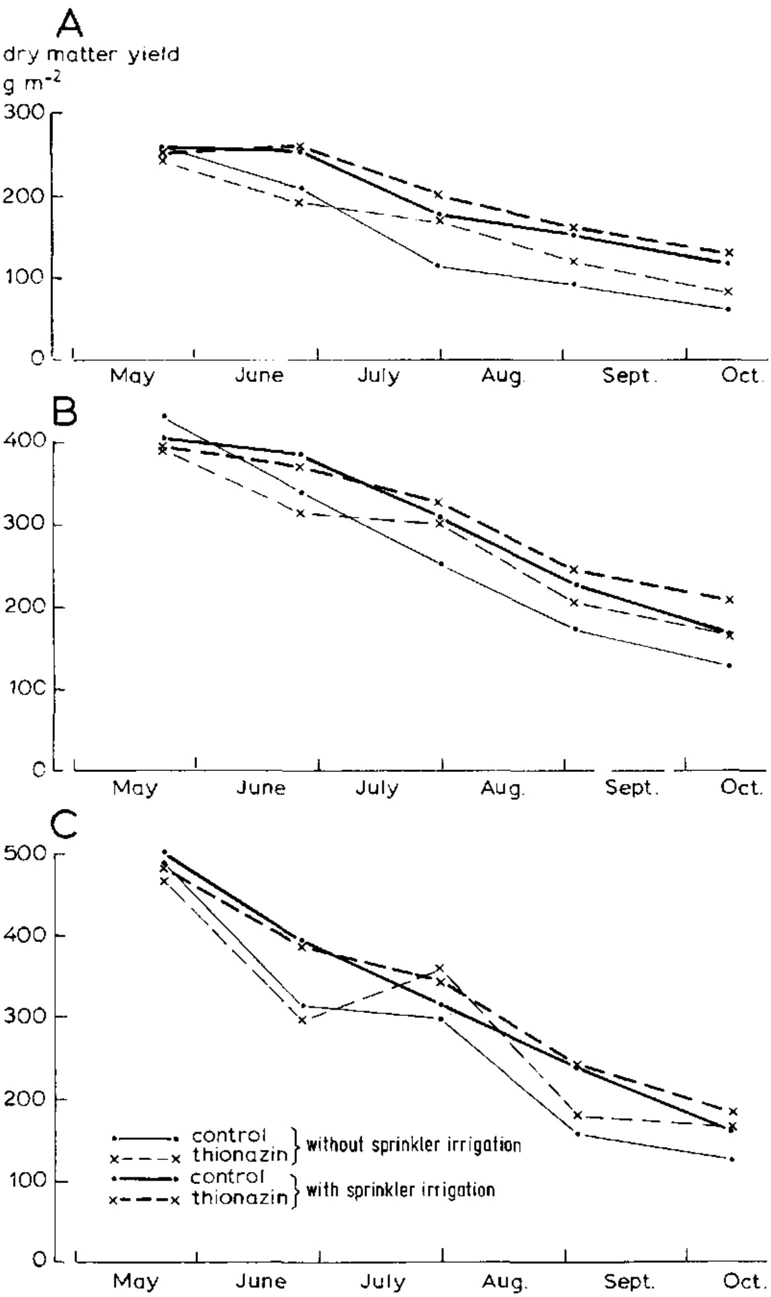

Figure 4. IBS 1631. Effect of thionazin on yield with and without sprinkler irrigation at 3 N levels in 1973. A. Mass of N applied per area at each cut 2.1 g m^{-2}. B. 8.6 g m^{-2}. C. 12.4 g m^{-2}.

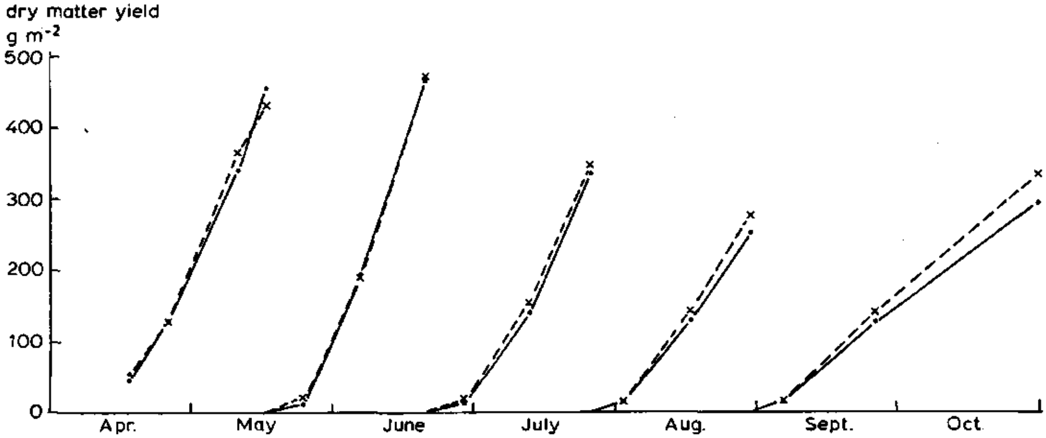

Figure 5. IBS 1545. Growth rates of a perennial ryegrass sward, with and without thionazin treatment, in successive cuts during the growing season of 1972. N fertilizer 12 g m^{-2} at each cut. Solid lines: untreated plots, dashed lines: thionazin treated plots.

small effect of dichlofenthion was demonstrated earlier (Ennik, 1968). In 1973, many pesticides were applied to a five-year old perennial ryegrass sward in East Flevoland, mostly at rates of 0.2 and 1.0 g of a.i. per m^2 for each cut (Table 5). As in other trials, many of the compounds tested depressed yield at the first cut, though not significantly. Toxicity was not involved, because in 11 out of 16 results the yield depression was greater at 0.2 g of a.i. per m^2 than at 1 g of a.i. per m^2. In later cuts, most of the tested compounds had a positive effect which on average increased as the season advanced. Significant increases over control occurred only in Cut 5 and over the whole year, and more often for fresh than for dry matter. Especially in Cut 5, 1 g was more effective than 0.2 g (Table 6). Some compounds e.g. carbaryl were probably toxic to the grass (Table 5). Insecticides/nematicides had greater effect than fungicides (benomyl, prothiocarb, captafol). It is remarkable, however, that a combination of both (thionazin + benomyl + prothiocarb) was very effective. These results show that pesticides other than thionazin, may also increase yield.

Results for a limited number of pesticides, tested in an old pasture dominated by ryegrass on sandy soil north of Wageningen in 1973 are presented in Table 7. There was a small insignificant decrease in dry yield of Cut 1. In Cut 3, dry yield also decreased, in contrast to fresh yield. Responsible for this is the relatively higher content of dry matter in the controls, most likely caused by greater contamination with soil. For this reason, the data on fresh yield are probably the more reliable. A significant positive effect occurred only in Cut 4. For thionazin, the greater effect than for other compounds may have resulted from the higher rate applied to previous cuts as Cut 4 itself was not treated.

For more information on the effect of fungicides, experiments were initiated in 1974: one on loam soil in East Flevoland and two others on sandy soil north of Wageningen, with some nematicides/insecticides and fungicides alone or in combination. The results for two successive years are presented in Table 8. Fungicides alone increased yield little, though significantly in two results only (IBS 1709 Cut 2 1974, and Cut 2 1975). The effect seemed greatest early in the season. Yield increase was considerable with nematicides/insecticides, especially in IBS 1710 Cuts 3 and 4 1974 and Cut 1 1975 and IBS 1709 Cut 2 1974 and Cut 2 1975. None of the nematicides increased the yield significantly more than the others, and thionazin at a high rate had no greater effect than low. The effect of nematicides was rather small in trial IBS 1711, especially in the first year. Adding fungicides to the nematicides increased the yield significantly only in IBS 1709 Cut 2 1975.

Table 2. IBS 1632. Overall effect of thionazin on dry matter yield (g m^{-2}) per cut with its level of insignificance (%) and the same effect split into the different starting times of N application and two N levels, with level of insignificance (%), α_1 and α_2 respectively, of the interactions.

Cuts	Dry matter yield (g m^{-2})	α thionazin effect (%)	N supply began at Cut					α_1 interaction (%)	N level (g m^{-2} for each cut)		α_2 interaction (%)
			1	2	3	4	5		8.4	12.0	
1973-05-22											
Untreated	331		331						278	385	
Thionazin	342		T342						286	398	
Effect	11	>25	11						9	13	>25
1973-06-26											
Untreated	389		415	364					365	414	
Thionazin	384		T414	T354					369	399	
Effect	-5	>25	-1	-10				>25	4	-15	>25
1973-07-31											
Untreated	269		244	315	249				254	285	
Thionazin	304		T299	T347	T267				278	331	
Effect	35	≦0.1	55	32	18			1-0.1	24	46	1-0.1
1973-09-04											
Untreated	215		173	194	252	241			206	224	
Thionazin	221		167	191	270	T254	T		206	235	
Effect	6	25-10	-6	-3	18	13		10-5	0	11	25-10
1973-10-12											
Untreated	185		168	148	177	251	182		184	187	
Thionazin	205		172	164	199	275	215		197	213	
Effect	20	≦0.1	4	16	22	24	33	25-10	14	26	25-10

T = thionazin applied (2.9 g a.i. m^{-2})

Table 3. IBS 1631. Effect of thionazin on dry matter yield (g m^{-2}) per cut without and with sprinkler irrigation and its level of insignificance (%), and the same effect split into three N levels, with level of insignificance (%) of the interactions.

Cuts	Dry matter yield (g m^{-2})	α thionazin effect (%)	N level (g m^{-2} for each cut)			α interaction (%)	Effect irrigation[2] (g m^{-2})
			2.1	8.6	12.4		
Without irrigation							
1973-05-22							
Untreated	393		259	432	488		
Thionazin	367		243	393	465		
Effect[1]	-26	1-0.1	-15	-39	-23	>25	
1973-06-26							
Untreated	288		209	341	315		
Thionazin	269		193	316	298		
Effect	-19	10-5	-16	-24	-17	>25	
1973-07-31							
Untreated	222		116	252	298		
Thionazin	275		170	301	355		
Effect	53	≤0.1	53	49	57	>25	
1973-09-03							
Untreated	141		93	172	158		
Thionazin	169		120	204	181		
Effect	27	≤0.1	27	32	23	>25	
1973-10-11							
Untreated	104		61	128	124		
Thionazin	137		83	164	163		
Effect	33	≤0.1	22	37	40	>25	
Year total							
Untreated	1148		738	1325	1383		
Thionazin	1217		809	1379	1462		
Effect	69	≤0.1	71	54	79	>25	
With irrigation							
1973-05-22							
Untreated	388		259	405	500		-5
Thionazin	377		252	395	484		10
Effect	-11	>25	-7	-10	-17	>25	
1973-06-26							
Untreated	344		255	384	393		56
Thionazin	338		260	371	384		69
Effect	-6	>25	5	-13	-8	>25	
1973-07-31							
Untreated	268		178	310	316		46
Thionazin	291		201	328	343		16
Effect	23	1-0.1	23	17	27	>25	
1973-09-03							
Untreated	206		152	228	239		65
Thionazin	217		163	246	242		48
Effect	11	25-10	11	18	2	>25	
1973-10-11							
Untreated	148		118	166	161		44
Thionazin	173		127	207	183		36
Effect	24	1-0.1	9	41	23	25-10	
Year total							
Untreated	1355		962	1494	1609		207
Thionazin	1395		1003	1547	1636		178
Effect	40	5-2.5	41	53	27	>25	

1. Small deviations of subtractions are due to rounding off.
2. For practical reasons the irrigated plots were not randomized so that the effect of irrigation and its interactions could not be analysed mathematically.

Table 4. IBS 1547. Effect of different growth regulators on fresh matter yield of perennial ryegrass as percentage of untreated (average yield per cut of untreated = 100%). Application before each cut; if growth regulator damaged the grass, one or more of the later applications were lowered or omitted. L = low rate, H = high rate; for details see Table 1.

Cut	Untreated		Thionazin		TIBA		Ethephon		Daminozide	
	little water	much water	L	H	L	H	L	H	L	H
1972-05-17	95	105	106	106	89	121	97	95	95	102
1972-06-20	104	96	110	109	108	95	96	98	101	103
1972-07-25	99	101	109	115	96	101	98	92	96	99
1972-08-29	100	100	110	110	102	101	98	100	103	95
1972-10-31	98	102	114	114	99	99	97	102	103	102
Total	99	101	110	111	99	103	97	97	100	100
Cut	**Azauracil**		**Chlorflure-col-methyl**		**Chlormequat**		**DNOC**		**Malathion**	
	L	H	L	H	L	H	L	H	L	H
1972-05-17	103	87	106	105	103	91	92	99	98	105
1972-06-20	92	92	100	94	99	104	66	92	100	99
1972-07-25	98	94	103	94	99	102	71	55	97	101
1972-08-29	92	80	101	95	103	108	85	67	102	99
1972-10-31	109	109	104	96	101	98	108	105	103	102
Total	99	92	103	97	101	101	84	84	100	101

Table 5. IBS 1630. Effect of different pesticides on fresh and dry matter yield of a perennial ryegrass ley as percentage of untreated (average yield per cut of untreated = 100%). Treatment before each cut, except Cut 5. For trade name and formulation of compounds see Table 10.

Compound	Rate per cut (g a.i. m^{-2})	Fresh matter						Dry matter					
		1973 05-21	06-25	07-30	09-03	10-11	total	1973 05-21	06-25	07-30	09-03	10-11	total
Untreated (g m^{-2})		3380	1850	2010	1690	1030	9980	526	346	282	236	146	1543
Untreated (%)		100	100	100	100	100	100	100	100	100	100	100	100
Nematic./insectic.													
Tirpate	0.2	98	100	105	94	111	100	92	105	110	97	107	99
Tirpate	1.0	101	104	109	105	108	104	103	104	103	102	103	102
Fensulfothion	0.2	98	100	92	99	118	99	94	104	92	100	111	99
Fensulfothion	1.0	98	108	105	107	136[1]	108	96	106	103	106	123	104
Aldicarb	0.2	90	107	104	110	115	102	93	112	103	106	108	102
Aldicarb	1.0	94	108	119	116	126	109	97	107	115	112	117	106
Fenamiphos	0.2	98	102	101	107	106	101	95	105	100	103	102	99
Fenamiphos	1.0	102	105	107	114	126	106	100	102	101	107	114	101
Carbofuran	0.2	90	97	105	122	123	103	98	109	101	113	116	104
Carbofuran	1.0	96	109	107	123	145[1]	110	95	103	108	113	128[2]	102
Terbufos	0.2	101	105	109	112	138[1]	109	103	104	104	107	124	105
Terbufos	1.0	95	107	111	123	144[1]	109	96	113	104	113	130[1]	106
Oxamyl	0.2	94	103	102	100	99	99	90	102	99	99	97	97
Oxamyl	1.0	96	106	108	123	105	106	92	109	104	118	100	103
Methomyl	1.0	93	99	113	110	133[1]	105	93	104	108	106	119	103
Phorate	0.2	90	107	101	118	123	103	93	111	99	115	118	103
Phorate	1.0	99	102	103	116	146[1]	108	98	105	101	113	132[1]	105
Thionazin	0.2	101	104	107	123	119	109	104	105	105	113	110	106
Thionazin	1.0	92	102	107	115	132[1]	105	92	103	103	111	119	101
Thionazin	2.9	94	115	114	121	136[1]	110	86	109	108	111	124	102
Trichloronate	0.2	96	108	105	119	136[1]	108	90	111	99	113	119	101
Trichloronate	1.0	94	116	104	107	135[1]	107	97	111	105	106	125	106
Parathion	0.2	109	95	112	97	119	106	111	98	107	97	110	105
Parathion	1.0	93	107	106	126	144[1]	108	91	107	101	114	129[2]	102

Table 5. Continued.

Compound	Rate per cut (g a.i. m^{-2})	Fresh matter 1973 05-21	06-25	07-30	09-03	10-11	total	Dry matter 1973 05-21	06-25	07-30	09-03	10-11	total
Chlorfenvinphos	0.2	91	108	96	112	134[1]	102	90	112	94	112	124	102
Chlorfenvinphos	1.0	96	108	98	107	138[1]	105	96	108	98	103	124	103
Carbaryl	0.2	94	97	104	99	94	97	94	97	108	102	93	98
Carbaryl	1.0	99	117	103	99	94	102	99	110	105	97	94	100
Dimethoate	0.2	102	106	98	102	101	102	103	102	98	100	98	100
Dimethoate	1.0	91	100	104	115	114	101	94	105	104	111	111	102
Diazinon	0.2	86	113	103	118	130[2]	106	89	112	98	112	120	104
Diazinon	1.0	97	104	111	116	133[1]	107	96	106	107	104	120	103
Bromophos	0.2	88	105	108	119	140[1]	105	91	112	102	110	125	103
Bromophos	1.0	112	100	115	120	144[1]	114[1]	105	96	108	111	128[2]	106
Temephos	1.0	97	106	98	100	120	101	97	106	97	104	112	100
Fungic.													
Benomyl	0.15	97	112	83	104	116	100	97	110	87	106	112	100
Prothiocarb	0.15	95	99	100	101	108	99	96	100	100	100	106	100
Captafol	1.0	92	106	109	109	107	102	94	107	107	102	104	101
Combination													
Thionazin + benomyl + prothiocarb	2.9+0.15+0.15	90	117	113	127	147[1]	112[2]	92	116	110	118	131[1]	108

1. Significant increase over control where $\alpha \leq 1$ (%). α = level of insignificance.
2. Significant increase over control where $\alpha \leq 5$ (%).

Table 6. IBS 1630. Yield per cut at high rate of applied chemical (1 g a.i. m^{-2} for each cut) as percentage of yield at low rate (0.2 g a.i. m^{-2} for each cut). Averaged for 16 chemicals. α = level of insignificance for difference between high and low rate.

Cut	Yield		α (%)	
	fresh	dry	fresh	dry
1973-05-21	102	101	>25	>25
1973-06-25	103	100	10-5	>25
1973-07-30	104	103	2.5-1	10-5
1973-09-03	105	102	2.5-1	25-10
1973-10-11	109	107	≤0.1	≤0.1
Total	103.5	101.5	≤0.1	2.5-1

Table 7. IBS 1633. Effect of some pesticides on fresh and dry matter yield of an old pasture dominated by ryegrass as percentage of untreated (average yield per cut of untreated = 100%). Treatment before each cut, except Cut 4. For trade name and formulation of compounds see Table 10.

Compound	Rate per cut (g a.i. m^{-2})	Fresh matter					Dry matter				
		1973					1973				
		05-16	06-19	08-03	10-05	total	05-16	06-19	08-03	10-05	total
Untreated (g m^{-2})		3450	2480	3380	1300	10610	536	408	520	267	1731
Untreated (%)		100	100	100	100	100	100	100	100	100	100
Thionazin	2.9	100	107	105	166[1]	112[3]	99	103	85	144[2]	103
Fensulfothion	0.6	104	104	106	123[3]	107	96	105	88	114	98
Aldicarb	0.6	102	106	101	123[3]	105	93	101	82	115	95
Tirpate	0.6	106	98	104	117[3]	105	97	96	89	111	96
Oxamyl	0.6	85	111	96	113	98	87	110	82	111	95
Fenamiphos	0.6	103	103	98	124[3]	104	104	101	86	120	100

1. Significant increase over control and all compounds where α ≤ 1 (%). α = level of insignificance.
2. Significant increase over control and all compounds where α ≤ 5 (%).
3. Significant increase over control where α ≤ 10 (%).

Table 8. IBS 1709, 1710, 1711. Effect of fungicides and some nematicides/insecticides, separately or in combination, on dry matter yield of three pastures dominated by ryegrass in two successive years, as percentage of untreated (average yield per cut of untreated = 100%). For trade names and formulations see Table 10. Ben. = benomyl, Pr. = prothiocarb, Th. = thionazin, Ald. = aldicarb, Fe. = fensulfothion.

Compound	Rate per cut[4] (g a.i. m^{-2})	IBS 1709					IBS 1710					IBS 1711					
		1974					1974					1974					
		05-31	07-16	08-21	10-21	total	06-10	07-24	09-03	10-22	total	05-31	07-04	08-06	09-04	10-17	total
Untreated (g m^{-2})		662	430	284	272	1647	501	398	316	209	1424	1039	385	363	329	305	2422
Untreated (%)		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Ben.+pr.	0.15+0.15	113	111[1]	107	100	109	106	106	100	101	104	100	105	103	103	99	101
Th.	1.0	95	106[1]	109	107	102	110	107	122[2]	132[1]	115	101	100	103	99	99	101
Th.+ben.+pr.	1.0+0.15+0.15	101	110[1]	111[3]	103	105	100	112[2]	127[1]	122[2]	112	103	108	103	102	100	103
Th.	2.9	100	111[1]	103	102	104	113	100	121[2]	122[2]	113	94	92	102	101	99	97
Th.+ben.+pr.	2.9+0.15+0.15	97	111[1]	107	115	105	102	104	116[2]	127[1]	109	94	95	104	99	102	97
Ald.	1.0	101	116[1]	109	110	108	100	102	119[2]	122[2]	108	103	97	104	103	100	102
Ald.+ben.+pr.	1.0+0.15+0.15	105	107[1]	111[3]	113	108	99	113[2]	119[2]	129[1]	112	97	102	106	111[3]	99	101
Fe.	1.0	96	108[1]	110	97	102	112	103	111	107	109	99	101	105	105	98	101
Fe.+ben.+pr.	1.0+0.15+0.15	99	114[1]	109	104	106	111	107	107	113	109	103	105	106	108	105	105
		1975					1975					1975					
		05-21	06-27	08-05	10-02	total	05-23	07-14	09-04	11-11	total	05-27	07-01	08-05	10-08		total
Untreated (g m^{-2})		556	290	358	274	1478	506	332	159	216	1214	801	286	317	333		1737
Untreated (%)		100	100	100	100	100	100	100	100	100	100	100	100	100	100		100
Ben.+pr.	0.15+0.15	93	113[1]	95	100	98	112	87	89	103	101	102	103	97	107		102
Th.	1.0	98	113[1]	93	101	100	119[2]	96	110	101	108	105	108	92	112		104
Th.+ben.+pr.	1.0+0.15+0.15	97	120[1]	105	106	105	110	92	131	96	105	104	107	101	109		105
Th.	2.9	104	116[1]	106	102	107	114	95	133	112	111	107	96	103	106		104
Th.+ben.+pr.	2.9+0.15+0.15	96	131[1]	103	103	106	112	82	121	108	104	101	95	105	109		102
Ald.	1.0	97	109[1]	107	103	103	109	92	113	102	104	109[2]	95	99	109		105
Ald.+ben.+pr.	1.0+0.15+0.15	101	124[1]	111	101	108	124[1]	93	102	98	108	101	108	96	115		104
Fe.	1.0	105	110[1]	96	108	104	103	95	145	93	105	104	117[2]	102	109		107
Fe.+ben.+pr.	1.0+0.15+0.15	101	126[1]	95	108	106	122[2]	95	104	109	110	103	112	101	109		106

1. Significant increase over control where $\alpha \leq 1$ (%). α = level of insignificance.
2. Significant increase over control where $\alpha \leq 5$ (%).
3. Significant increase over control where $\alpha \leq 10$ (%).
4. If applied, see Section 2, Trials IBS 1709, 1710, 1711.

3.2 EFFECT ON NEMATODE POPULATION

Soil nematodes were counted in most of the trials reported in this paper to check whether the effect of thionazin and other pesticides on grass resulted from their death.

In the rather recently reclaimed soil of IBS 1432, only two genera of parasitic nematodes (*Paratylenchus* and *Criconemoides*) were found (Table 9), both at low concentrations. Nevertheless the yield of dry matter increased considerably with thionazin (Fig. 1A). In trials IBS 1546 and 1547, initiated one year after IBS 1432 on the same field, the same nematode genera were present as in IBS 1432, but at higher concentrations, especially of *Paratylenchus* and 'other tylenchids' (of which 90% belonged to one unidentified species) in IBS 1546. Though the nematode number of replicates within treatment was not always inversely related to the yield (compare IBS 1546, Plot 22 with Plot 27), the combined data of these trials showed a negative correlation between nematode concentration and total yield of dry matter over the season (Fig. 6). Where nematode concentration was relatively high, high yields were lacking. Such a correlation was absent in most other trials. Trials IBS 1631 and 1632, initiated in 1973, were also on the same field. Concentrations of *Paratylenchus* were high in control plots of IBS 1632, but a comparison with IBS 1630 (next paragraph and Fig. 7) makes it doubtful whether they were high enough to be considered as harmful to grass.

Nematode counts of IBS 1630, on the same field as the trials of the preceding paragraph, are presented in Table 10. The 'Untreated Series 1' was sampled at 4 September and 12 October; the difference shows that the nematodes had increased sharply, as in trial IBS 1633 (Table 11, compare total number of tylenchids of control in Cuts 3 and 4). From the data of 12 October, the nematicides/insecticides have been classed into three groups according to their effect on nematode concentration in the soil; in Table 10, these groups are followed by a group of fungicides and the combination of thionazin and fungicides. Nematodes were distinctly suppressed by Tirpate (3M Company, St. Paul, Minnesota), fensulfothion, aldicarb, fenamiphos, carbofuran, terbufos, oxamyl, and less by methomyl, phorate, thionazin, trichloronate, parathion, chlorfenvinphos and carbaryl. A small or negligible effect was obtained with dimethoate, diazinon, bromophos and temephos. Among the fungicides, benomyl had a small suppressing effect, whereas prothiocarb and captafol seemed to have increased the nematode concentration. As shown by Figure 7 there was no relation between concentration of tylenchid nematodes (mainly *Paratylenchus*, Table 10) and yield on 11 October up to a concentration in soil of at least 100 000 tylenchids (70 000 *Paratylenchus*) per litre. High concentration of nematode did not preclude high yields.

Highest yield response (Table 5) often failed to coincide with the strongest nematicidal effect (Table 10). Among the compounds with the strongest nematicidal effect, only half caused a significant increase in yield, whereas all the compounds of moderate nematicidal action except carbaryl significantly increased yield. Two of the compounds with little nematicidal activity, bromophos and diazinon, significantly increased yield as well.

Within the group with the strongest nematicidal effect, the yield-increasing effect of some compounds had perhaps been counteracted by crop damage. Perhaps the nematicidal ef-

Table 9. IBS 1432, 1546, 1547, 1631, 1632. Number of free-living root nematodes per 0.01 litre of soil in the 0-5 cm layer per treatment (bulked from three replicates) or per replicate. All these trials were on the same field, which was under grass since September 1968.

Trial	Treatment	Plot number	Yield (g d.m. m^{-2}) Cut 5	Yield (g d.m. m^{-2}) total[1]	Sampling date	Nematode concentration (number per 0.01 litre) *Para-tylenchus*	*Crico-nemoides*	*Meloi-dogyne*	other tylenchids[2]	saprozoic nematodes
1432	6- 8 g N m^{-2} per cut: control				1971-09-08	249	2		100	53
	thionazin					17	4		14	11
	8-12 g N m^{-2} per cut: control					60	3		103	51
	thionazin					51	2		112	16
1546	control	11	290	1760	1972-12-08	201	9		575	295
		12	237	1660		742	22		570	214
		25	249	1700		504	19		408	252
	thionazin, single application	7	291	1690		113	0		148	252
	(1972-05-30) to Cut 2	22	251	1720		12	0		433	90
		27	257	1730		403	7		555	282
	thionazin, single application	3	316	1800		79	2		395	349
	(1972-08-02) to Cut 4	17	294	1720		54	0		310	182
		30	277	1710		177	1		260	76
1547	control, little water	14	263	1830	1972-12-08	39	0	0	232	190
		40	271	1730		226	32	13	289	187
		53	279	1770		239	0	0	167	149
	thionazin, 1.9 g m^{-2} per cut	10	275	1820		21	0		116	17
		30	319	1910		32	4		166	60
		46	308	1890		19	67		129	65
	thionazin, 3.8 g m^{-2} per cut	9	312	1850		23	6		295	19
		22	308	1940		37	0		33	63
		54	258	1800		128	0		284	98
1631	control, 12.4 g N m^{-2} per cut:				1973-09-04					
	without sprinkler irrigation					252	7		351	95
	with sprinkler irrigation					226	1		149	154
1632	12 g N m^{-2} per cut:				1973-09-04					
	control					1325	0		124	166
	thionazin to Cuts 1 to 3					28	1		29	68

1. Total = year total.
2. In Trial 1432 mainly *Aphelenchoides*, in Trials 1546 and 1547 90% belonged to one species with tylenchid stylet, in Trials 1631 and 1632 probably *Tylenchus* sp.

Table 10. IBS 1630. Number of free-living root nematodes per 0.01 litre of soil. Bulked samples of three replicates from each treatment, including three untreated series of three replicates each. Dates of sampling: 1973-09-04 Untreated Series 1 only and 1973-10-12 all treatments. Column 2: g. = granules, e.c. = emulsiable concentrate, w.p. = wettable powder, a.s. = aqueous solution, with indications of the mass concentration (g l^{-1}) or mass fraction (g kg^{-1}) of active ingredient.

Trade name	Formulation	Common name	Rate per cut (g a.i. m^{-2})	Nematode concentration (number per 0.01 litre)				
				Para-tylenchus	*Criconemoides*	other tylenchids	total tylenchids	saprozoic nematodes
1973-09-04								
Untreated Series 1				280	10	161	*451*	203
1973-10-12								
Untreated Series 1				756	8	326	*1090*	364
Untreated Series 2				536	22	446	*1004*	428
Untreated Series 3				614	28	344	*986*	344
av. untreated 12 Oct.				*635*	*19*	*372*	*1027*	*379*
Tirpate	g.-100		0.2	28	18	54	*100*	132
Tirpate	g.-100		1.0	116	0	0	*116*	54
Terracur P	g.-50	fensulfothion	0.2	104	22	118	*244*	92
Terracur P	g.-50	fensulfothion	1.0	64	0	0	*70*	42
Temik	g.-100	aldicarb	0.2	172	4	12	*188*	168
Temik	g.-100	aldicarb	1.0	72	0	6	*78*	36
Nemacur	g.-50	fenamiphos	0.2	170	12	18	*200*	110
Nemacur	g.-50	fenamiphos	1.0	112	0	2	*114*	64
Curaterr	g.-100	carbofuran	0.2	132	8	24	*164*	200
Curaterr	g.-100	carbofuran	1.0	26	4	6	*36*	98
AC 92,100	g.-100	terbufos	0.2	136	4	18	*158*	104
AC 92,100	g.-100	terbufos	1.0	168	8	8	*184*	72
Vydate	g.-100	oxamyl	0.2	34	16	22	*72*	138
Vydate	g.-100	oxamyl	1.0	106	20	52	*178*	146
Lannate	w.p.-250	methomyl	1.0	164	2	96	*262*	144
Thimet	g.-100	phorate	0.2	330	0	98	*428*	70
Thimet	g.-100	phorate	1.0	200	4	36	*240*	84
Nemafos	e.c.-480	thionazin	0.2	302	6	138	*446*	82
Nemafos	e.c.-480	thionazin	1.0	164	0	60	*224*	288
Nemafos	e.c.-480	thionazin	2.9	200	6	32	*238*	108
Phytosol	g.-75	trichloronate	0.2	354	26	138	*518*	166
Phytosol	g.-75	trichloronate	1.0	240	0	76	*316*	103
Parathion	e.c.-250	parathion	0.2	256	18	314	*588*	160
Parathion	e.c.-250	parathion	1.0	400	4	132	*536*	156

Table 10. Continued.

Trade name	Formulation	Common name	Rate per cut (g a.i. m^{-2})	Nematode concentration (number per 0.01 litre)				
				Para-tylenchus	*Crico-nemoides*	other tylenchids	total tylenchids	saprozoic nematodes
Sapecron	g.-100	chlorfenvinphos	0.2	310	4	306	*620*	282
Sapecron	g.-100	chlorfenvinphos	1.0	312	4	160	*476*	234
Liro-Carbaryl	g.-500	carbaryl	0.2	440	0	206	*646*	223
Liro-Carbaryl	g.-500	carbaryl	1.0	294	2	248	*544*	308
Rogor	e.c.-400	dimethoate	0.2	332	8	198	*538*	182
Rogor	e.c.-400	dimethoate	1.0	500	2	430	*932*	410
Basudine	e.c.-200	diazinon	0.2	682	20	240	*942*	252
Basudine	e.c.-200	diazinon	1.0	434	28	224	*686*	318
Nexion	e.c.-400	bromophos	0.2	500	12	496	*1008*	178
Nexion	e.c.-400	bromophos	1.0	560	22	320	*902*	286
Abate	g.-20	temephos	1.0	508	8	436	*952*	292
Benlate	w.p.-500	benomyl	0.15	516	4	264	*784*	388
Previcur	a.s.-700	prothiocarb	0.15	1216	34	238	*1488*	194
Orthodifolatan	w.p.-800	captafol	1.0	1200	20	350	*1570*	384
Nemafos + Benlate + Previcur		thionazin + benomyl + prothiocarb	2.9+0.15+0.15	114	0	70	*184*	204

Table 11. IBS 1633. Number of free-living nematodes per 0.01 litre of soil during the season (between brackets as percentage of control). Bulked samples of three replicates from each treatment, including two control series of three replicates each. Trade mark and formulation of compounds as in Table 10. P = *Pratylenchus*, Pa = *Paratylenchus*, T = *Tylenchorhynchus*, Hel = *Helicotylenchus*, Tr = *Trichodorus*, L = *Longidorus*, Hl = *Heterodera* larvae, O = other tylenchids.

Treatment	Rate for each cut (g a.i. m^{-2})	Cut	Nematode concentration (number per 0.01 litre)									
			P	Pa	T	Hel	Tr	L	Hl	O	total tylenchids	saprozoic nematodes
Control Series 1		(1973-04-26)		63	62	33			1	30	*189*	242
Control Series 1		1 (1973-05-16)	0	80	62	32	4		20	158	*356 (100)*	378 (100)
Control Series 1		2 (1973-06-19)	2	51	40	5	1	3	2	87	*191 (100)*	431 (100)
Control Series 1		3 (1973-08-03)	10	208	16	1			0	103	*338 (100)*	338 (100)
Control Series 1		4 (1973-10-05)	18	530	52	8	12			126	*746 (100)*	372 (100)
Control Series 2		4 (1973-10-05)	10	466	26	0	0			196	*698*	348
Oxamyl	0	(1973-04-26)		35	39	37			15	22	*148*	177
	0.6	1 (1973-05-16)	8	22	26	16	8		4	86	*170 (48)*	168 (44)
	0.6	2 (1973-06-19)	1	1	9	5	0	0	0	18	*34 (18)*	154 (36)
	0.6	3 (1973-08-03)	0	0	1	0			0	3	*4 (1)*	70 (21)
	0	4 (1973-10-05)	2	10	3	1	0			8	*24 (3)*	73 (20)
Fenamiphos	0	(1973-04-26)		45	41	10			31	23	*150*	302
	0.6	1 (1973-05-16)	0	6	62	8	8		2	44	*130 (37)*	304 (80)
	0.6	2 (1973-06-19)	0	0	11	2	2	0	0	16	*31 (16)*	175 (41)
	0.6	3 (1973-08-03)	4	2	6	0			0	11	*23 (7)*	77 (23)
	0	4 (1973-10-05)	0	2	1	0	0			1	*4 (0.5)*	35 (10)
Aldicarb	0.6[1]	4 (1973-10-05)	0	2	0	0	0			3	*5 (0.7)*	32 (9)
Tirpate	0.6[1]	4 (1973-10-05)	0	6	2	1	0			8	*17 (2)*	170 (47)
Fensulfothion	0.6[1]	4 (1973-10-05)	3	218	31	4	5			63	*324 (45)*	96 (27)
Thionazin	2.9[1]	4 (1973-10-05)	2	80	4	1	0			12	*99 (14)*	106 (29)

1. Before Cut 1 to 3 only.

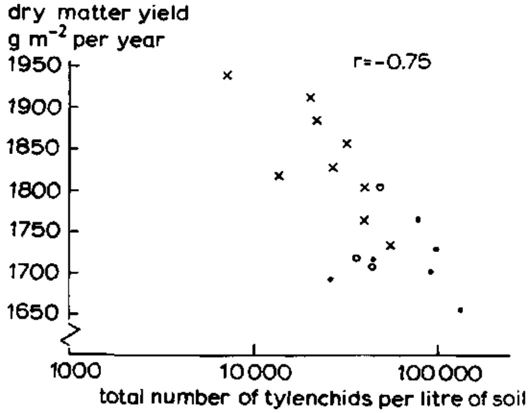

Figure 6. IBS 1546 and 1547. Relation between totalled yield (whole year) and total number of tylenchids in December 1972. • 1546, control or 3.8 g m^{-2} thionazin before Cut 2; o 1546, 3.8 g m^{-2} thionazin before Cut 4; x 1547, control or thionazin (1.9 or 3.8 g m^{-2} for each cut).

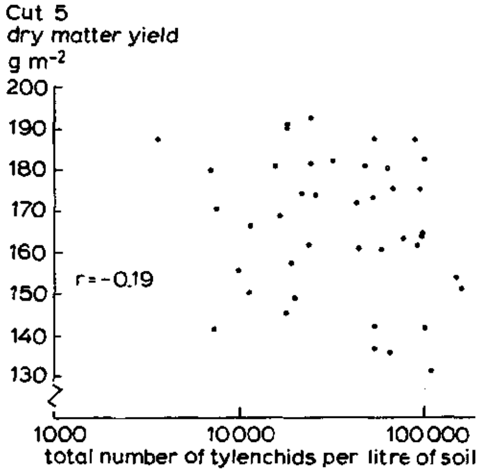

Figure 7. IBS 1630. Relation between yield of Cut 5 and total number of tylenchids in October 1973.

fect of compounds with little or no effect on nematode concentration had been underestimated because their action was of short duration, so that since the last pesticide application (9 August) nematode concentration had already recovered at the time of sampling (12 October), or because of a reduced ability of the surviving nematodes to attack plants. But as a whole, the results suggest that the increase in yield after application of nematicides/insecticides is not particularly related to the kill of nematodes.

A more mixed nematode population was present in the soil of IBS 1633, on sandy soil north of Wageningen (Table 11). Whether the nematodes were harmful to the grass is questionable. Nematode control was highly effective by oxamyl, fenamiphos, aldicarb and Tirpate, moderately by fensulfothion, and intermediate by thionazin (in spite of its high rate). Nevertheless the yield-increasing effect of fensulfothion was not less than that of the other nematicides, and that of thionazin considerably greater (Table 7, Cut 4) suggesting that there yield increase was not related to nematode kill. But the sudden rise in concentration of nematodes in the control plots from Cut 3 to Cut 4 (Table 11) coincided with a considerable increase in yield response by nematicide treatment (Table 7), thus pointing to a relation between the two factors. Sampling of the soil on 14 November revealed that the arthropod fauna was very low, while leatherjackets, grubs of cockchafer, wireworms and larvae of *Bibionidae* were absent, so that the insecticidal effect of the chemicals on yield may be neglected.

Nematode concentrations from trials IBS 1709, 1710 and 1711 are presented in Table 12. Yield increase with the pesticides was highest for IBS 1710 (Table 8), and more frequent counts were made on that field. In 1974, when pesticides had been applied at least thrice, aldicarb was most effective in killing nematodes in the soil, followed by thionazin. Fensulfothion was less effective. The fungicides, among which benomyl is known to have some nematicidal activity, had no effect. In 1975, when the application of nematicides/insecticides was restricted to Cut 1, only aldicarb completely eliminated nematodes for the rest of the season, and fensulfothion seemed to have a more-lasting suppressive effect on saprozoic nematodes.

Nematode concentrations varied greatly in IBS 1710. In 1974 (e.g. Column 17 in Table 12), they showed no distinct relation with grass yield (Column 5), but as a whole yields tended to be lower at concentrations above 20 000 tylenchids per litre (Fig. 8). At Cut 4 in October 1974, the untreated plots and the plots treated with benomyl plus prothiocarb alone or in combination with fensulfothion showed poorer growth and yellow discoloration of the grass. These lower yielding treatments had the highest concentrations of nematodes (Table 12), though such a relation did not exist between the replicates of one treatment. In 1975, no discoloration was observed and at the end of that year, concentrations of nematodes were low and presumably innocuous.

In IBS 1711, on young reclaimed land in East Flevoland, free-living nematodes were scarce, especially in 1974, and the favourable effect of pesticides on grass yield was correspondingly small or absent (Table 8). It is doubtful, however, whether the small yield response to pesticides and the low concentration of nematodes were directly related, because numbers of other potential parasites may also have been low in this new soil.

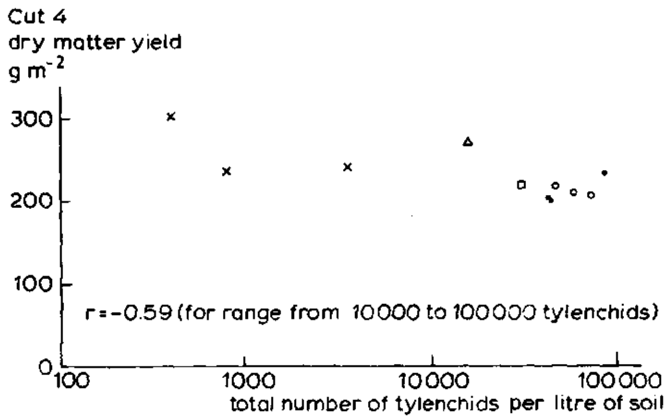

Figure 8. IBS 1710. Relation between yield of Cut 4 and total number of tylenchids in October 1974. ● untreated, △ thionazin, x aldicarb, □ fensulfothion, o benomyl plus prothiocarb.

Table 12. IBS 1709, 1710, 1711. Number of free-living nematodes per 0.01 litre of soil in October 1974 and 1975. Samples of each replicate per treatment separately or bulked samples of three replicates per treatment. P = *Pratylenchus*, Pa = *Paratylenchus*, T = *Tylenchorhynchus*, Hel = *Helicotylenchus*, Tr = *Trichodorus*, Hem = *Hemicycliophora*, C = *Criconemoides*, Hl = *Heterodera* larvae, Ml = *Meloidogyne* larvae, O = other tylenchids, S = saprozoic nematodes, Tot = total tylenchids.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Trial	Treatment	Replicate	Rate per cut (g a.i. m^{-2})	Dry matter yield Cut4 (g m^{-2})	Nematode concentration (number per 0.01 litre)											
					P	Pa	T	Hel	Tr	Hem	C	Hl	Ml	O	S	Tot
1974																
1709	Untreated Ser. 1				12	142	158	50	22	0		16		190	662	*590*
	benomyl + prothiocarb		0.15+0.15		0	206	210	20	24	0		18		184	230	*662*
	thionazin		1.0		2	46	14	4	8	2		6		74	302	*156*
	aldicarb		1.0		0	6	0	0	0	0		22		8	242	*36*
	fensulfothion		1.0		10	70	126	34	14	2		16		98	188	*370*
1710	Untreated Ser. 1			200	16	28	250	2	18	0		4		110	222	*428*
	Untreated Ser. 2			200	4	150	192	4	20	6		12		64	356	*452*
	Untreated Ser. 3			230	2	664	142	2	14	2		18		26	388	*870*
	benomyl + prothiocarb	1	0.15+0.15	210	10	354	224	0	46	0		10		112	756	*756*
	benomyl + prothiocarb	2	0.15+0.15	220	4	232	154	4	10	4		10		62	426	*480*
	benomyl + prothiocarb	3	0.15+0.15	210	2	248	284	4	8	10		8		34	330	*598*
	aldicarb	1	1.0	300	0	4	0	0	0	0		0		0	174	*4*
	aldicarb	2	1.0	240	2	22	0	0	0	0		0		12	108	*36*
	aldicarb	3	1.0	240	0	6	0	0	0	0		0		2	344	*8*
	thionazin		1.0	280	0	144	6	0	8	0		2		2	88	*162*
	fensulfothion		1.0	220	2	168	82	0	14	0		22		20	164	*308*
1711	Untreated Ser. 1				0	0	4	2	0	0	2	0		292[1]	510	*300*
	benomyl + prothiocarb		0.15+0.15		0	0	4	0	0	0	6	0		206	322	*216*
	aldicarb		1.0		0	0	0	0	0	0	2	0		8	170	*10*
1975																
1709	Untreated Ser. 1				3.5	137.5	13.0	0.5	0			3.0		912.0		
	benomyl + prothiocarb		0.15+0.15		12.5	82.5	13.0	0	0			3.5		949.0		
	thionazin		1.0		5.5	259.5	9.5	3.5	4.0			3.5		752.5		

Table 12. Continued.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Trial	Treatment	Rep- li- cate	Rate per cut (g a.i. m^{-2})	Dry matter yield Cut4 (g m^{-2})	Nematode concentration (number per 0.01 litre)											
					P	Pa	T	Hel	Tr	Hem	C	Hl	Ml	O	S	Tot
	aldicarb		1.0		0	0	0	0	0			0			652.0	
	fensulfothion		1.0		2.5	12.5	36.5	3.0	0.5			7.0			376.0	
1710	Untreated Ser.	1		230	4.0	11.0	22.5	3.0	0			3.0			959.0	
	Untreated Ser.	2		220	0.5	10.0	32.5	5.5	0.5			2.5			1329.5	
	benomyl + prothiocarb		0.15+0.15		3.5	12.0	44.0	1.5	0.5			1.5			830.0	
	aldicarb		1.0		0	1.0	0	0	0			0			750.0	
	thionazin		1.0		3.5	9.5	7.0	0	0			0.5			636.0	
	fensulfothion		1.0		0.5	4.5	22.5	0	0			4.5			390.0	
1711	Untreated Ser.	1		350	12.5	73.5	0.5	0	0			0	3.0		905.0	
	Untreated Ser.	2		330	0.5	0	1.5	0	0			0	6.5		837.5	
	benomyl + prothiocarb		0.15+0.15		2.0	36.5	1.5	0	0			0	5.0		1050.5	
	aldicarb		1.0		0	0	0	0	0			0	0		698.5	

1. mainly *Tylenchus agricola*.

4 Discussion

A general review of the results for thionazin for all trials is presented in Table 13 and Figure 9. Both with low and high dressings of N, and independent of yield, the annual yield increment of dry matter averaged to 116 g m^{-2}: a relative gain over control of 13% and 8% for low and high dressings, respectively. With low dressings gain of dry matter was related to increased nitrogen yield (Ennik, 1972), which may be due to an increase in mineral N in soil, or/and to reduced losses of plant material or a better exploitation of the soil by the roots when parasites were killed. A similar effect could be obtained with more fertilizer N. With high dressings, nitrogen was not limiting and the yield gain with thionazin could not be realized by more fertilizer N. Though in the individual trials, no interaction was found between thionazin effect and N level (except Table 2, Cut 3), it seems a coincidence that, averaged for all trials, the effect is equal with low and high dressings, since it is not equal if the average effect is split according to soil type (Table 14). The gain in yield for each cut is shown in Table 15. The effect was small in Cut 1 (in almost half of the trials it was negative; Table 13), but considerable in later cuts.

Eissa (1971) reported an average yield increase of 19% after partial soil sterilization in 34 Dutch grasslands chosen at random and of unknown parasite infestation. In seven trials free from parasitic nematodes, yield increased by 5%. Because absolute yields and amounts of applied N are not mentioned, the absolute yield gain and the possible contribution of increased availability of nitrogen in the soil cannot be assessed. In another trial, reported by Eissa, on soil infested with many *Pratylenchus crenatus, Tylenchorhynchus dubius* and *Rotylenchus robustus*, partial sterilization increased yield by 15%, only in Cuts 2-5.

In England, Henderson & Clements (1974) found up to 30% yield increase in five out of six pesticide/grass-yield trials at high rates of N fertilizer, even though no invertebrate species was present in unusually large numbers (Clements, 1974). Yield losses were attributed to the activities of the normally occurring grassland fauna. The data of Henderson & Clements indicate that the response to pesticide treatment was not weaker in the first than in later cuts.

In earlier experiments, no relation was found between yield response and nematode numbers (Ennik, 1972). But proportionate changes in yield and tillering suggested that thionazin activates dormant buds. This is not supported by the present results: first, because in contrast to thionazin, growth regulators that may break dormancy had no effect on yield (Table 4), secondly because a similar yield response was also obtained with pesticides other than thionazin. Therefore, increased tillering after pesticide treatment was a result rather than the cause of improved growth. Most likely, the pesticide effect is related to elimination of parasitic soil organisms or to systemic action on leaf-dwelling

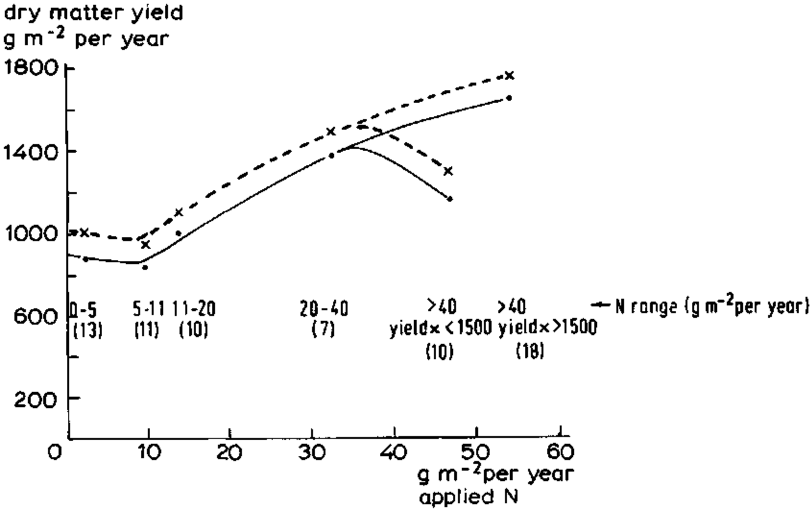

Figure 9. Average effect of thionazin in relation to nitrogen application. For high N the data have been split into two classes: yield with thionazin higher or lower than 1500 g m^{-2} per year. In brackets the number of observations within the range of N application concerned. Detailed information in Table 13. Solid lines: control plots, dashed lines: thionazin treated plots.

organisms. In accordance the yield of perennial ryegrass growing on nutrient solution was not increased by adding 5 or 10 mg l^{-1} a.i. thionazin to the solution. Addition of 20 or 40 mg l^{-1} harmed the grass and diminished yield.

In a few trials yield seemed inversely related to nematode number. That such a relation was not found in most trials may be due to inadequacy of sampling technique, caused by unequal distribution of nematodes within plots or fluctuations in concentration during the season. An other explanation may be that other parasites, either in combination with nematodes or alone, or even non-parasitic organisms were involved, although application of fungicides did not indicate that fungi interfered. In trial IBS 1630 (Table 5) the combination of thionazin with fungicides increased the yield more than thionazin alone, but the difference was insignificant, and in IBS 1709, 1710 and 1711 (Table 8) there was a significantly favourable effect of additional fungicides only in one cut of one trial.

Most of our trials were situated on old sandy soil with a normal fauna of soil organisms, or on young reclaimed loam soil in a new polder with few nematodes, and probably also few other soil organisms. Accordingly, yield response to thionazin application was higher on old than on new soil (Table 14), although there is no evidence of a direct relation between yield response and concentration of nematodes. Yield response tended to be higher with high dressing of nitrogen, but as a relatively greater proportion of the trials with high dressing were on loam, yield increase was the same at low and high N when averaged for all trials (Fig. 9).

To ensure optimum results, the rate of thionazin was high (Table 13). The experiments were not planned to produce a practical method of pesticide application to grassland, but to measure yield response. In the few experiments with different rates, the effects of 1 g of a.i. thionazin per square metre for each cut and more were similar, but a rate of

Table 13. Survey of the effect of thionazin application on pasture yield (g dry matter per m^2). C = control, Th = thionazin, Eff = effect.

Trial	Year	Soil type	Age pasture (years)	N level[1]	N supply[2] (g m^{-2} per year)	Th supply[2] (g m^{-2} per year)	Dry matter yield (g m^{-2}) Cut 1 C	Cut 1 Th	Cut 1 Eff	Cut 2 C	Cut 2 Th	Cut 2 Eff
903	1966	sand	2	L	1x2.3	3x3.1	188	265	+ 77	212	372	+160
	1967		3	L	2x2.3	3x2.7	156	186	+ 30	122	188	+ 66
	1968		4	L	4x2.3	4x3.8	253	270	+ 17	198	240	+ 42
	1969		5	L	4x3.3	4x3.8	168	201	+ 33	193	189	- 4
	1969		5	H	4x11.4	4x3.8	lost			408	467	+ 59
904	1966	sand	5	L	1x2.3	4x3.0	286	260	- 26	142	158	+ 16
905	1966	sand	3	L	1x2.3	3x3.1	407	427	+ 20	257	278	+ 21
	1967		4	L	2x2.3	3x2.7	403	418	+ 15	233	278	+ 45
	1968		5	L	4x2.3	4x3.8	195	233	+ 38	239	280	+ 41
	1969		6	L	4x3.4	4x3.8	218	283	+ 65	236	260	+ 24
	1969		6	H	4x11.7	4x3.8	389	503	+114	302	321	+ 19
907	1966	sand	1	L	0	4x3.0	488	517	+ 29	221	196	- 25
	1967		2	L	2x2.3	3x2.7	346	417	+ 71	256	277	+ 21
	1968		3	L	4x2.3	4x3.8	267	276	+ 9	242	253	+ 11
908	1966	sand	1	L	0	4x3.0	369	338	- 31	85	106	+ 21
	1967		2	L	2x2.3	3x2.7	390	450	+ 60	190	213	+ 23
	1968		3	L	4x2.3	4x3.8	214	238	+ 24	192	228	+ 36
	1969		4	L	4x3.2	4x3.8	212	311	+ 99	138	185	+ 47
	1969		4	H	4x11.8	4x3.8	358	387	+ 29	266	355	+ 89
1001	1966	sand	0	L	0	a	556	512	- 44	259	263	+ 4
	1967		1	L	1x2.3	b	324	375	+ 51	253	270	+ 17
	1968		2	L	5x2.8	a	536	492	- 44	150	176	+ 26
1002	1966	sand	1	L	0	a	441	491	+ 50	341	388	+ 47
	1967		2	L	1x2.3	b	391	464	+ 73	329	367	+ 38
	1968		3	L	5x2.8	a	576	624	+ 48	180	182	+ 2
1161	1968	sand	4	L	5x2.3	4x4.1	395	285	-110	206	244	+ 38
	1968		4	M	5x6.9	4x4.1	559	486	- 73	393	362	- 31
	1968		4	H	5x11.5	4x4.1	504	572	+ 68	379	431	+ 52
	1969		5	L	4x2.3	4x4.1	351	246	-105	211	317	+106
	1969		5	M	4x6.9	4x4.1	384	443	+ 59	385	485	+100
	1969		5	H	4x11.5	4x4.1	410	364	- 46	449	575	+126
1162	1968	loam	0	L	5x2.1	5x4.1	240	227	- 13	478	506	+ 28
	1968		0	M	5x7.2	5x4.1	407	373	- 34	487	533	+ 46
	1968		0	H	5x12.2	5x4.1	443	430	- 13	452	474	+ 22
	1969		1	L	4x2.1	4x4.1	272	272	0	142	180	+ 38
	1969		1	M	4x7.2	4x4.1	357	371	+ 14	422	458	+ 36
	1969		1	H	4x12.2	4x4.1	262	392	+130	555	510	- 45
1163	1968	sand	4	L	c	4x2.2	433	362	- 71	228	241	+ 13
	1969		5	L	d	3x2.2	384	386	+ 2	237	409	+172
1393	1970	peat	old	L	3x3.5	3x4.1	410	396	- 14	135	264	+129
	1970			H	3x14.0	3x4.1	541	463	- 78	236	289	+ 53
	1971			L	3x3.5	3x4.1	416	477	+ 61	249	336	+ 87
	1971			H	3x14.0	3x4.1	643	559	- 84	264	271	+ 7
	1972			L	3x4.3	2x4.1	420	510	+ 90	361	346	- 15
	1972			H	e	2x4.1	509	548	+ 39	287	271	- 16
	1973			L	4x4.0	3x2.6	438	416	- 22	327	405	+ 78
	1973			H	4x12.0	3x2.6	498	490	- 8	400	461	+ 61
1432	1971	loam	2	M	5x6.9	g	310	333	+ 23	405	431	+ 26
	1971		2	H	5x9.5	g	349	353	+ 4	458	460	+ 2
1545	1972	loam	3	M	f	5x3.8	335	310	- 25	300	323	+ 23
	1972		3	H	5x12.0	5x3.8	456	432	- 24	464	471	+ 7

Cut 3			Cut 4			Cut 5			total[4]		
C	Th	Eff	C	Th	Eff	C	Th	Eff	C	Th	Eff
146	252	+106							547	890	+343
grazed			75	138	+ 63				352	514	+162
191	223	+ 32	195	245	+ 50				838	977	+139
156	212	+ 56	147	190	+ 43				665	792	+127
316	433	+117	263	263	0				987	1163	+176
316	362	+ 46	191	283	+ 92				935	1061	+126
261	332	+ 71							927	1035	+108
187	232	+ 45	grazed						825	927	+102
237	269	+ 32	153	236	+ 83				824	1016	+192
203	254	+ 51	106	192	+ 86				763	989	+226
213	304	+ 91	116	249	+133				1020	1377	+357
196	227	+ 31	171	201	+ 30				1075	1141	+ 66
211	230	+ 19	243	259	+ 16				1056	1182	+126
213	228	+ 15	242	251	+ 9				963	1011	+ 48
287	288	+ 1	194	213	+ 19				934	945	+ 11
224	247	+ 23	80	108	+ 28				885	1018	+133
252	296	+ 44	193	229	+ 36				853	987	+134
139	213	+ 74	104	210	+106				594	920	+326
239	328	+ 89	165	251	+ 86				1027	1322	+295
189	237	+ 48	95	120	+ 25				1099	1131	+ 32
104	161	+ 57	89	120	+ 31				769	924	+155
268	278	+ 10	196	208	+ 12	106	119	+ 13	1254	1273	+ 19
215	256	+ 41	104	128	+ 24				1100	1263	+163
164	206	+ 42	98	122	+ 24				981	1158	+177
grazed			261	274	+ 13	74	76	+ 2	1089	1155	+ 66
169	195	+ 26	273	255	- 18	146	218	+ 72	1232	1175	- 57
348	301	- 47	338	370	+ 32	181	217	+ 36	1745	1754	+ 9
343	359	+ 16	329	377	+ 48	148	227	+ 79	1710	1914	+204
113	177	+ 64	103	137	+ 34				789	880	+ 91
352	363	+ 11	198	237	+ 39				1321	1513	+192
319	526	+207	216	265	+ 49				1378	1746	+368
131	141	+ 10	163	174	+ 11	170	173	+ 3	1180	1216	+ 36
272	276	+ 4	371	391	+ 20	270	248	- 22	1800	1816	+ 16
294	286	- 8	454	497	+ 43	292	305	+ 13	1933	1986	+ 53
124	154	+ 30	128	155	+ 27				667	760	+ 93
211	270	+ 59	245	253	+ 8				1233	1353	+120
205	367	+162	214	290	+ 76				1233	1556	+323
374	373	- 1	336	320	- 16				1371	1296	- 75
248	276	+ 28							870	1073	+203
79	149	+ 70							624	809	+185
206	246	+ 40							983	998	+ 15
166	210	+ 44							830	1023	+193
229	266	+ 37							1136	1095	- 41
307	302	- 5							1088	1159	+ 71
392	394	+ 2							1188	1213	+ 25
237	298	+ 61	75	98	+ 23				1077	1217	+140
302	356	+ 54	45	118	+ 73				1244	1424	+180
209	244	+ 35	240	330	+ 90	107	164	+ 57	1269	1502	+233
200	243	+ 43	265	352	+ 87	148	185	+ 37	1438	1593	+155
165	183	+ 18	216	255	+ 39	97	141	+ 44	1113	1212	+ 99
336	347	+ 11	253	275	+ 22	294	334	+ 40	1803	1859	+ 56

Table 13. Continued.

Trial	Year	Soil type	Age pasture (years)	N level[1]	N supply[2] (g m^{-2} per year)	Th supply[2] (g m^{-2} per year)	Dry matter yield (g m^{-2})					
							Cut 1			Cut 2		
							C	Th	Eff	C	Th	Eff
1546	1972	loam	3	H	5x11.6	1x3.8[3]	440	402	- 38	450	460	+ 10
1547	1972	loam	3	H	5x11.3	h	446	462	+ 16	415	437	+ 22
1630	1973	loam	4	H	5x12.8	j	526	494	- 32	346	366	+ 20
1631k	1973	loam	4	L	5x2.1	4x2.9	259	243	- 16	209	193	- 16
k	1973		4	M	5x8.6	4x2.9	432	393	- 39	341	316	- 25
k	1973		4	H	5x12.4	4x2.9	489	465	- 24	315	298	- 17
l	1973		4	L	5x2.1	4x2.9	259	252	- 7	255	260	+ 5
l	1973		4	M	5x8.6	4x2.9	405	395	- 10	384	371	- 13
l	1973		4	H	5x12.4	4x2.9	500	484	- 16	393	384	- 9
1632	1973	loam	4	M	5x8.4	m	278	286	+ 8	365	369	+ 4
	1973		4	H	5x12.0	m	385	398	+ 13	414	399	- 15
1633	1973	sand	15	H	4x11.9	3x2.9	536	532	- 4	408	422	+ 14
1709	1974	sand	2	H	4x11.9	n	662	646	- 16	430	466	+ 36
	1975		3	H	4x12.5	p	556	561	+ 5	290	332	+ 42
1710	1974	sand	6	H	4x11.9	n	501	559	+ 58	398	412	+ 14
	1975		7	H	4x12.2	p	506	590	+ 84	332	317	- 15
1711	1974	loam	1	H	5x13.1	q	1039	1017	- 22	385	369	- 16
	1975		2	H	4x13.1	p	801	852	+ 51	286	292	+ 6

Cut 3			Cut 4			Cut 5			total[4]		
C	Th	Eff	C	Th	Eff	C	Th	Eff	C	Th	Eff
322	334	+ 12	260	266	+ 6	258	285	+ 27	1730	1747	+ 17
371	389	+ 18	284	284	0	274	296	+ 22	1789	1867	+ 78
282	297	+ 15	236	263	+ 27	146	172	+ 26	1543	1590	+ 47
116	170	+ 54	93	120	+ 27	61	83	+ 22	738	809	+ 71
252	301	+ 49	172	204	+ 32	128	164	+ 36	1325	1379	+ 54
298	355	+ 57	158	181	+ 23	124	163	+ 39	1383	1462	+ 79
178	201	+ 23	152	163	+ 11	118	127	+ 9	962	1003	+ 41
310	328	+ 18	228	246	+ 18	166	207	+ 41	1494	1547	+ 53
316	343	+ 27	239	242	+ 3	161	183	+ 22	1609	1636	+ 27
254	278	+ 24	206	206	0	184	197	+ 13	1287	1336	+ 49
285	331	+ 46	224	235	+ 11	187	213	+ 26	1495	1576	+ 81
520	442	- 78	267	384	+117				1731	1780	+ 49
284	301	+ 17	272	285	+ 13				1647	1698	+ 51
358	357	- 1	274	278	+ 4				1478	1528	+ 50
316	384	+ 68	209	266	+ 57				1424	1620	+196
159	194	+ 35	216	230	+ 14				1214	1330	+116
363	372	+ 9	329	329	0	305	301	- 4	2422	2390	- 32
317	309	- 8	333	363	+ 30				1737	1815	+ 78

1. L = low N (0-4.5 g m^{-2} for each cut); M = medium N (5.0-9.0 g m^{-2} for each cut); H = high N (9.5-14.0 g m^{-2} for each cut).
2. Code: a = yields are averages of the thionazin series 4x1.2, 4x2.4, 4x3.6, 4x4.8 and 1x7.1 (no significant yield differences between the series); b = yields are averages of the thionazin series 3x1.2, 3x2.4, 3x3.6, 3x4.8 and 1x7.1 (no significant yield differences between the series); c = 2.3+3.5+6.0+6.0 g N m^{-2}; d = 3.7+3.1+4.7 g N m^{-2}; e = 15.8+15.8+4.9 g N m^{-2}; f = 9.0+4x5.2 g N m^{-2}; g = averages of the thionazin series 6x3.8 (first application in December of the preceding year) and 5x3.8. Yields of both series were about the same; h = average of 5x1.9 and 5x3.8 (yields were about the same for both rates); j = average of 4x0.2, 4x1.0 and 4x2.9 (no relation between yield and rate); k = without sprinkler irrigation; l = with sprinkler irrigation; m = varying from 1x2.9 to 3x2.9 (see Table 2); n = average of 3x1.0 and 3x2.9 (no relation between yield and rate); p = average of 1x1.0 and 1x2.9 (no relation between yield and rate); q = average of 4x1.0 and 4x2.9 (no relation between yield and rate).
3. See Section 2, Trial 1546 for scheme of application.
4. The discrepancy between annual yield and the sum of the yields of different cuts in some trials is due to correction for differences in soil fertility (independently calculated for each cut and the annual yield), or to the fact that the average yield of one or more cuts and the annual yield are calculated from less replicates than the averages of the other cuts.

Table 14. Yield response of grass (g dry matter per m^2 per year) after thionazin treatment on old sand soil and young reclaimed loam soil. Between brackets the number of observations.

	N supply		
	low	medium	high
Dry matter yield ($g\ m^{-2}$ per year)			
sand	121 (26)	101 (2)	186 (10)
loam	60 (4)	89 (7)	80 (12)

Table 15. Effect of thionazin on dry matter yield ($g\ m^{-2}$ and as percentage of control) for each cut with low or high dressings of N, averaged for all trials. Between brackets the number of observations.

N supply ($g\ m^{-2}$ per year)	Effect on dry matter yield ($g\ m^{-2}$ and as percentage of control)					
	Cut 1 May	Cut 2 June	Cut 3 July	Cut 4 Aug./Sept.	Cut 5 Oct.	Annual effect
low N (0-20)	13 (34) 4%	39 (34) 17%	39 (32) 19%	33 (27) 21%	20 (6) 18%	116 (34) 13%
high N (>40)	8 (25) 2%	20 (26) 5%	41 (26) 14%	40 (23) 16%	30 (11) 14%	116 (26) 8%

0.2 g of a.i. per square metre for each cut was less effective (Table 6).

Alberda (1968) has shown that the actual production of grassland under optimal conditions of management and nutrient supply remained below the potential production calculated by simulation from photosynthetic and other growth data, especially later in the season. Yield gain by pesticide treatment diminished the difference between actual and potential production but not completely.

Summary

Thionazin treatment of pasture resulted in an average increase in annual yield of dry matter of 116 g m^{-2}; the increase was greater for old sand soil than for young reclaimed loam soil. The effect was small or negative in the first cut, but became considerable and positive as the season advanced. When applied for the first time to the later cuts the increase in yield was immediate and of normal magnitude. The effect was greater with drought than with a near optimum water supply. Similar increases were obtained with other nematicides/insecticides, but not with growth regulators. Adding fungicides to the nematicides/insecticides usually had no further effect on yield. No reliable relation was found between yield response and death of nematodes.

Acknowledgements

Thanks are due to Dr J.A. Bunt, Department of Nematology, Wageningen and the Plant Protection Service, Wageningen for identification and counting of nematodes, to the private industries for providing the chemicals (Ligtermoet Chemie N.V., Rotterdam, Neth.; Bayer-Agrochemie N.V., Arnhem, Neth.; Schering Nederland N.V., Boxtel, Neth.; AAgrunol N.V., Groningen, Neth.; Cyanamid of Great Britain Limited, Gosport, Hampshire, England) and to Dr W. Dijkshoorn for critical reading of the manuscript.

References

Alberda, Th., 1968. Maximale grasproduktie. Stikstof nr. 60 : 538-545.

Clements, R.O., 1974. The effect of pesticide application on the yield of herbage. Pre-congress Proceedings XII International Grassland Congress, Moscow, Section 'Chemicalization of grassland farming': 81-87.

Eissa, M.F.M., 1971. The effect of partial soil sterilization on plant parasitic nematodes and plant growth. Mededelingen Landbouwhogeschool Wageningen 71-14. 129 p.

Ennik, G.C., 1968. Growth-promoting effects of some biocides on grass. Netherlands Journal of Agricultural Science 16 : 132-135.

Ennik, G.C., 1972. Dry matter yield response of pasture grass to application of Nemafos (thionazin). Netherlands Journal of Agricultural Science 20 : 81-96.

Henderson, I.F. & R.O. Clements, 1974. The effect of pesticides on the yield and botanical composition of a newly-sown ryegrass ley and of an old mixed pasture. Journal of the British Grassland Society 29: 185-190.

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