Nematol. medit. (1982) 10: 9-19

Department of Agriculture, P.R.I., Burnley, Vic. 3121, Australia:
Department of Agriculture, C.E.C., Dooen, Vic. 3401, Australia;
Department of Agriculture, M.R.S., Walpeup, Vic. 3507, Australia.

A COMPARISON OF LOW VOLUME, IN-ROW APPLICATIONS OF NEMATICIDES AT SEEDING, FOR CONTROL OF THE CEREAL CYST NEMATODE (*HETERODERA AVENAE*) IN WHEAT.

by
R. H. BROWN, D. L. PYE and G. T. STRATFORD

Previous investigations in Victoria, Australia (Meagher and Rooney, 1966; Barry *et al.*, 1974; Meagher and Brown, 1974) have shown that crop rotation can provide good control of the cereal cyst nematode (*Heterodera avenae* Woll.) with resultant increases in grain yield. This practice is not always feasible economically, especially on farms of limited size, and better control of the nematode may ultimately be achieved using resistant varieties (Brown and Meagher, 1970). In the meantime, however, the use of nematicides has been considered (Brown *et al.*, 1970; Brown, 1972, 1973; Meagher *et al.*, 1978). These studies have shown that a wide range of nematicides, fumigant, non-volatile, and sterilant, can provide excellent control of *H. avenae.*

This paper reports further results on the control of *H. avenae* in wheat, using low rates of fumigant and non-volatile nematicides applied in the drill row at seeding.

Material and Methods

The experiments were done in the season 1974 to 1979 at various sites in the Mallee and Wimmera districts of Victoria, on land infested with *H. avenae.*

Two fumigant and four non-volatile nematicides were used. The fumigants were DBCP [1, 2 dibromo 3 chloropropane, 41% v/v] and EDB [ethylene dibromide, 97% v/v]. The non-volatile nematicides were aldicarb [2, methyl 2 (methylthio) propionaldehyde 0- (methyl-

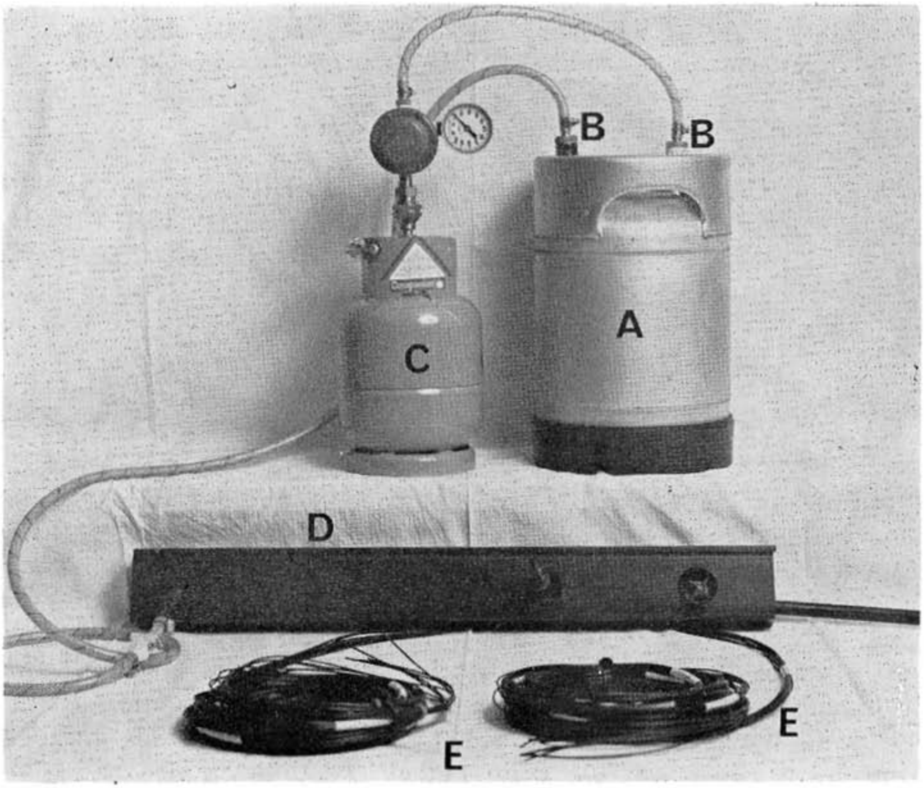

Fig. 1 - Equipment (Jectarow[R]) for low-volume application of liquid nematicides in a drill row at seeding. A. Stainless steel pre-mix container; B. Quick release hose connectors; C. Pressure source (LPG); D. Manifold unit (made from PVC irrigation fittings); E. Microtubes through which nematicides are applied.

carbamoyl) oxime, 10% granular], fenamiphos [ethyl 4 (methylthio) -m-tolyl isopropyl phosphoramidate, 43.6% w/v], oxamyl [S-methyl l- (dimethylcarbamoyl) -N- ((methylcarbamoyl) oxy) thioformidate, 24% v/v], and terbufos [S- (((1, 1-dimethylethyl)thio)methyl) 0,0-diethyl phosphorodithioate, 15% granular].

Between 1974 and 1977, DBCP was the only nematicide tested, and the application rates are listed in Tables I and II. The appropriate amount of nematicide needed to treat each plot was added to 10 l of water, in a drum mounted on the drill, and applied by gravity feed through polyethylene tubes (5 mm diameter) inserted down the backs of the tynes. The nematicide was applied directly in the drill

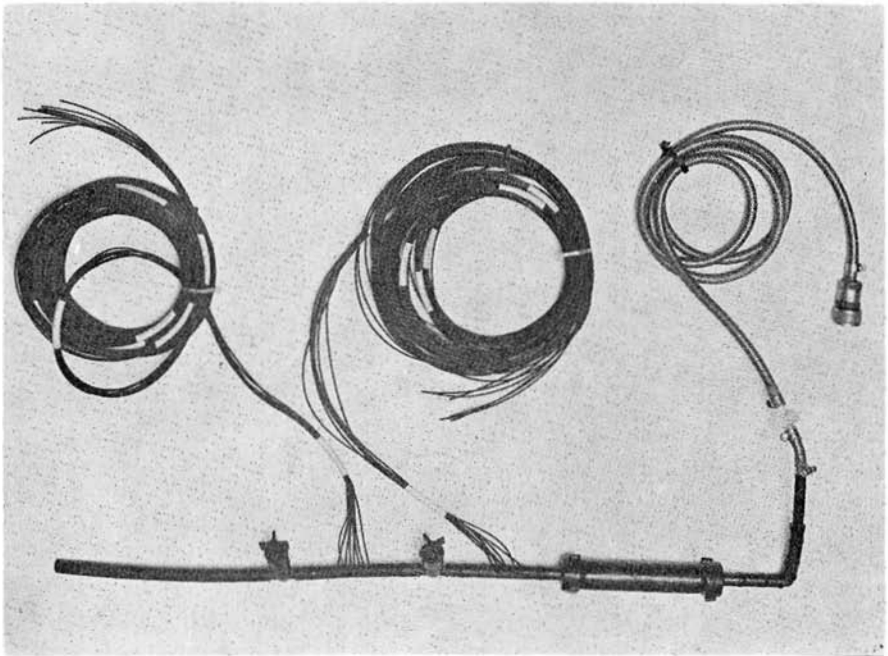

Fig. 2 - Jectarow[R] manifold unit with protective cover removed.

row at seeding. The rate of flow through each tube was regulated by adjustable needle valves made from brass.

In 1979, DBCP, EDB, and the liquid formulations of oxamyl and fenamiphos were applied undiluted using Jectarow (1) (a precision applicator) (Figs. 1 and 2). The microtubes of the applicator were taped behind the tynes, and the nematicides were applied in the drill row at seeding. The nematicides were held in 9 l capacity stainless steel pressure vessels (2), and applied at pressure of 70 kPa. Propane in a conventional barbecue-type gas cylinder was used to pressurise the system.

Granular aldicarb was applied by hand to the plot surface immediately before sowing, while terbufos was mixed with superphosphate and applied in the drill row using the method of Brown (1973).

All experiments were sown as randomised bloks, with four re-

(1) Registered tradename of Agchem Pty. Ltd., Adelaide, S. A. Australia.
(2) Mytton Rodd Pty Ltd., Fishermens Bend, Vic., Australia.

Table I - *The effect of nematicide treatments on cereal cyst nematode* (H. aveane) *populations, and grain yields at Mallee sites in 1974 and 1977.*

TREATMENT (l/ha)		Walpeup '74		Walpeup '77		Sea Lake '77	
		Cysts (No/plant)	Yield (t/ha)	Cysts (No/plant)	Yield (t/ha)	Cysts (No/plant)	Yield (t/ha)
DBCP	1.5	41.0 (1.61)**	1.59*	20.0 (1.30)**	1.15**	50.0 (1.70)	0.53
DBCP	3.0	39.0 (1.59)**	1.84**	31.5 (1.33)**	1.16**	38.5 (1.58)**	0.55
DBCP	6.0	21.0 (1.32)**	1.77**	10.0 (1.00)**	1.31**	17.0 (1.22)**	0.74*
DBCP	12.0	4.0 (0.60)**	1.83**	6.0 (0.76)**	1.20**	6.0 (0.76)**	1.44**
Untreated		69.0 (1.84)	1.21	42.0 (1.62)	0.89	68.0 (1.83)	0.46
L.S.D. (P = 0.05)*		(0.07)	0.31	(0.12)	0.25	(0.15)	0.23
(P = 0.01)**		(0.10)	0.45	(0.17)	0.36	(0.21)	0.35

In brackets, log transformation.

Table II - *The effect of nematicide treatments on grain yields of wheat at cereal cyst nematode infested sites in the Wimmera, 1977.*

TREATMENT (l/ha)	GRAIN YIELD (t/ha)		
	Crymelon	Jung	Murra Warra
DBCP 1.5	1.13**	1.34**	1.28**
DBCP 3.0	1.13**	1.62**	1.38**
DBCP 6.0	1.21**	1.86**	1.83**
DBCP 12.0	1.57**	2.06**	2.21**
Untreated	0.71	1.06	0.59**
L.S.D. (P. = 0.05)*	0.23	0.20	0.28
(P = 0.01)**	0.33	0.27	0.39

plicates, and plot size was 1.4 x 30 m (i.e. 0.004 ha). The experiments were always sown in May (Mallee district), or June (Wimmera district), on land that had been winter fallowed (i.e. initial cultivation the previous July or August, with subsequent cultivations as necessary for weed control, until sowing). Between 1974 and 1977 wheat cv. Halberd (Mallee district) or cv. Olympic (Wimmera district) at the rate of 67 Kg/ha was sown with phosphorus (12 Kg/ha as superphosphate), applied with the seed. In 1979 wheat cv. Condor, at the same rate, was used in both districts.

Ten plants were collected at random from each plot (except at Wimmera sites in 1977), and assessed for numbers of white cysts using the method described by Brown (1973). Various growth parameters were measured 24 weeks after sowing in the 1979 experiments. The results (Table IV) are the mean of at least forty observations. Leaf areas were measured with an electronic planimeter (3).

Grain yields were determined at crop maturity.

Results

In every experiment in the Mallee district, application of DBCP at all rates significantly reduced the numbers of white cysts produced

(3) Paton Industries Pty. Ltd., St. Peters, S.A., Australia.

on plant roots (Table I). DBCP at the highest rate, 12 l/ha, always provided the best control.

All DBCP treatments, except 1.5 and 3.0 l/ha at Sea Lake, significantly improved grain yields (Table I).

Cyst numbers were not assessed in the experiments in the Wimmera district. All DBCP treatments significantly improved grain yields (Table II).

In the experiment in 1979 at Walpeup significant reductions in numbers of white cysts on plant roots followed the application of both oxamyl rates, DBCP at 7.4 l/ha, EDB at all rates, both rates of aldicarb and terbufos at 0.3 and 0.6 kg/ha (Table III). Only six treatments viz. aldicarb 4 kg/ha, DBCP 7.4 l/ha, and EDB, at all rates gave significant increases in grain yield (Table III).

All chemical treatments except fenamiphos at both rates, oxamyl 3.7 l/ha, and terbufos 0.3 kg/ha, significantly reduced the numbers of white cysts produced on plant roots in the experiment in 1979 at Sea Lake, site A (Table III).

With the exception of fenamiphos at the lower rate, all other treatments significantly improved grain yields.

EDB 11.1 l/ha gave the best nematode control, and provided the greatest yield increase (288 per cent, or 1240 kg/ha more than the untreated control).

All chemical treatments except fenamiphos at both rates, and oxamyl 3.7 l/ha, significantly reduced the numbers of white cysts produced on plant roots in the experiment in 1979 at Crymelon (Table III).

Only seven treatments viz. DBCP 3.7 l/ha, EDB 3.7, 7.4, and 11.1 l/ha, aldicarb at both rates and terbufos at the higher rate gave significant increases in grain yield (Table III).

All chemical treatments except fenamiphos at the lower rate significantly reduced the numbers of white cysts produced on plant roots in the experiment in 1979 at Sea Lake, site B (Table IV).

After 20 weeks, there were large differences between several treatments, in the growth parameters measured (Table IV). There were greater numbers of tillers and emerged heads in plots treated with aldicarb 4 kg/ha, or EDB, at all rates, than in other plots. All chemical treatments except terbufos 0.3, 0.6, and 0.9 kg/ha, provided significant increases in leaf area per plant. Plants from plots treated with EDB 7.4 and 11.1 l/ha had more than twice the leaf area of plants from untreated plots.

Table III - *The effect of nematicide treatments on cereal cyst nematode* (H. avenae) *populations, and grain yields at Mallee and Wimmera sites in 1979.*

TREATMENT		WALPEUP		SEA LAKE (A)		CRYMELON	
		Cysts (No/plant)	Yield (t/ha)	Cysts (No/plant)	Yield (t/ha)	Cysts (No/plant)	Yield (t/ha)
Fenamiphos 3.7	l/ha	27.5 (1.44)	1.32	83.9 (1.92)	0.61	199.5 (2.34)	2.80
Fenamiphos 7.4	l/ha	29.3 (1.47)	1.35	77.8 (1.90)	0.80*	176.2 (2.30)	2.73
Oxamyl 3.7	l/ha	41.6 (1.62)**	1.70	52.0 (1.72)	0.88**	214.1 (2.33)	2.84
Oxamyl 7.4	l/ha	8.6 (0.94)**	1.78	42.3 (1.63)**	0.80*	159.0 (2.20)**	2.77
DBCP 3.7	l/ha	26.3 (1.42)	1.71	14.0 (1.15)**	1.13**	113.9 (2.06)**	3.00**
DBCP 7.4	l/ha	12.3 (1.10)**	1.91*	9.1 (0.96)**	1.31**	73.8 (1.87)**	2.91
E.D.B. 1.85	l/ha	10.0 (1.00)**	2.03**	22.5 (1.35)**	1.14**	60.0 (1.78)**	2.79
E.D.B. 3.7	l/ha	5.1 (0.71)**	2.31**	12.7 (1.10)**	1.60**	113.1 (2.05)**	2.94*
E.D.B. 7.4	l/ha	7.9 (0.90)**	2.13**	4.7 (0.67)**	1.65**	51.0 (1.71)**	3.09**
E.D.B. 11.1	l/ha	11.8 (1.07)**	2.31**	2.6 (0.41)**	1.67**	1.4 (0.14)**	3.16**
Aldicarb 2.0	kg/ha	18.1 (1.26)**	1.57	14.2 (1.15)**	1.06**	39.1 (1.60)**	3.05**
Aldicarb 4.0	kg/ha	9.3 (0.97)**	1.93**	10.4 (1.02)**	1.28**	43.3 (1.64)**	3.05**
Terbufos 0.3	kg/ha	18.2 (1.26)**	1.81	64.7 (1.81)	0.93**	42.9 (1.63)**	2.82
Terbufos 0.6	kg/ha	14.0 (1.15)**	1.51	23.9 (1.38)**	0.99**	74.6 (1.87)**	2.82
Terbufos 0.9	kg/ha	30.5 (1.48)	1.83	34.5 (1.54)**	0.99**	53.8 (1.73)**	2.93*
Untreated		30.2 (1.48)	1.39	67.2 (1.83)	0.43	218.5 (2.34)	2.82
L.S.D. (P = 0.05)*		(0.10)	0.46	(0.10)	0.30	(0.10)	0.11
(P = 0.01)**		(0.14)	0.61	(0.13)	0.41	(0.13)	0.15

In brackets, log transformation.

Table IV - *The effect of nematicide treatments on cereal cyst nematode* (H. avenae) *populations, and growth and yield of wheat, at Sea Lake (site B), in 1979.*

TREATMENT			WEEKS AFTER SOWING: 16	20			30
			Cysts (No/plant)	Tillers (No/m of row)	Emerged Heads (No/m of row)	Leaf Area (cm²/plant)	Yield (t/ha)
Fenamiphos	3.7	l/ha	49.4 (1.69)	49.7	7.2 (0.86)	8.9**	0.55
Fenamiphos	7.4	l/ha	41.0 (1.61)*	50.5	2.2 (0.35)**	9.6**	0.34
Oxamyl	3.7	l/ha	37.8 (1.58)**	51.7	7.7 (0.89)	6.2*	0.51
Oxamyl	7.4	l/ha	21.3 (1.33)**	51.0	7.9 (0.90)*	8.0**	0.59
D B C P	3.7	l/ha	24.6 (1.39)**	51.2	6.9 (0.78)	9.2**	0.64*
D B C P	7.4	l/ha	3.1 (0.49)**	52.5	8.0 (0.90)*	8.1**	0.84**
E. D. B.	1.85	l/ha	16.7 (1.22)**	60.5**	16.6 (1.22)**	8.4**	0.93**
E. D. B.	3.7	l/ha	12.6 (1.10)**	63.5**	24.2 (1.38)**	9.7**	1.00**
E. D. B.	7.4	l/ha	5.0 (0.70)**	65.0**	22.4 (1.35)**	11.1**	1.14**
E. D. B.	11.1	l/ha	1.0 (0.00)**	66.0**	21.4 (1.33)**	13.3**	1.10**
Aldicarb	2.0	kg/ha	7.5 (0.88)**	49.5	7.4 (0.87)	8.3**	0.75**
Aldicarb	4.0	kg/ha	5.2 (0.72)**	58.5**	9.7 (0.99)**	9.5**	0.83**
Terbufos	0.3	kg/ha	34.2 (1.53)**	47.2	2.9 (0.46)**	5.1	0.33
Terbufos	0.6	kg/ha	27.8 (1.44)**	46.0	3.9 (0.60)**	5.4	0.37
Terbufos	0.9	kg/ha	31.1 (1.49)**	45.5	3.0 (0.48)**	6.0	0.43
Untreated			52.8 (1.72)	46.5	6.2 (0.79)	5.1	0.32
L.S.D. (P = 0.05)*			(0.10)	6.3	(0.11)	1.0	0.30
(P = 0.01)**			(0.13)	8.4	(0.14)	1.3	0.40

In brackets, log transformation.

All treatments except fenamiphos, oxamyl and terbufos significantly improved grain yields.

EDB, 7.4 l/ha provided the greatest yield increase (256 per cent, or 820 kg/ha more than the untreated control).

Discussion

The results from these experiments show that nematicides applied at low rates, in the drill row at sowing, can provide good control of *H. avenae* and improve grain yields. Population levels varied between field sites, and from year to year, and the total number of white cysts observed on the roots of untreated plants varied accordingly.

In most of our experiments there were significant increases in grain yield. Unfavourable seasonal conditions in 1975 forced us to abandon our experiments, and in 1977 prevented larger increases in yield from being obtained, despite the observed earlier good responses in plant growth.

Our earlier experiments, 1974-1977, were concerned only with DBCP because we believed that it was the nematicide most suitable for use by cereal growers. On the heavy clay soils of the Wimmera, DBCP was phytotoxic to wheat in a few of our experiments (Brown, unpublished), and grain yields were correlated inversely with rate of application. Despite the likely benefits from using DBCP, it was withdrawn from sale for environmental considerations before it could be recommended to growers.

Our 1979 and subsequent experiments have shown that several nematicides, particularly EDB and terbufos, provide excellent responses at rates which are commercially viable. Plants from EDB treated plots (particularly those from Sea Lake, site B) were clearly more vigorous than those from other plots. They had greater leaf areas, more tillers per plant, matured earlier supporting earlier observations by Hynes (1937), Brown *et al.* (1970) and Meagher *et al.* (1978) that soil-borne diseases affect the phenology of wheat.

EDB and terbufos are now registered for use on cereals in Victoria and South Australia, at a cost of c. $AUS 14/ha. With wheat currently valued at $AUS 150/tonne, a yield increase of only 0.1 t/ha is required to cover the cost of the treatment.

EDB is applied at the recommended rate of 3.7 l/ha, using Jectarow. In our experiments application rates ranging from 1.85 l/ha

(½ recommended rate) to 11.1 l/ha (3 times the recommended rate) were used without signs of phytotoxicity. On the heavier soils of the Wimmera there is evidence (Brown, unpublished data) that rates higher than 3.7 l/ha may be needed. Indeed, in recent experiments, treatment with 7.4 l/ha provided significantly better yields than treatment with 3.7 l/ha.

Terbufos (15G) is applied at the recommended rate of 0.6 kg a.i./ha, either through a small seeds box attached to the drill, or as a mixture with superphosphate.

Further research is proceeding with various nematicides, including oxamyl and carbofuran as seed treatments. With more than 2 million hectares infested with *H. avenae* in Victoria and South Australia, there are excellent prospects for chemical control of the nematode using any one of several possible nematicides.

We thank the many growers on whose properties field experiments were located; officers of the Mallee Research Station, and Cereal Experimental Centre for sowing and harvesting plots, and collecting plant samples: Mr. C. Felstead, Mr. D. O'Rourke, Mrs. G. Andrews and Mrs. L. Clarkson for laboratory assistance, and Mr. R. Jardine for statistical analyses.

This study was part of a project financed jointly by the Australian Wheat Industry Research Council, and the Wheat Industry Research Committee of Victoria.

SUMMARY

The effect of low volume, in-row applications of several nematicides at seeding, on cereal cyst nematode (*Heterodera avenae*) and on grain yields of wheat, were examined between 1974 and 1979 in the Mallee and Wimmera districts of Victoria, Australia. From 1974 to 1977, DBCP (1, 2 dibromo 3 chloropropane, 41% v/v) was the only nematicide used. In most experiments, application of DBCP at rates ranging from 1.5 to 12 l/ha significantly reduced the numbers of white cyst produced, and all nematicide treatments except DBCP at 1.5 and 3 l/ha at Sea Lake in 1977 significantly improved grain yields. In 1979, E.D.B. (ethylene dibromide, 97% v/v), aldicarb, fenamiphos, oxamyl, and terbufos were also used. There were significant reductions in the numbers of white cysts per plant following the application of some nematicides, in each of the four experiments. The responses varied between sites, but the best control followed treatment with E.D.B. at rates ranging from 3.7 to 11.1 l/ha. Significant yield increases were also obtained in each experiment, and the best yields followed treatment with E.D.B. at 7.4 or 11.1 l/ha.

LITERATURE CITED

BARRY, E. R., BROWN, R. H. and ELLIOTT, B. R., 1974. Cereal cyst nematode (*Heterodera avenae*) in Victoria: influence of cultural practices on grain yields, and nematode populations. *Aust. J. Exp. Agric. Anim. Husb., 14*: 566-571.

BROWN, R.H., 1972. Chemical control of the cereal cyst nematode (*Heterodera avenae*) in Victoria. A comparison of systemic and contact nematicides. *Aust. J. Exp. Agric. Anim. Husb., 12*: 662-667.

BROWN, R. H., 1973. Chemical control of the cereal cyst nematode (*Heterodera avenae*). A comparison of methods and rates of application of two systemic nematicides. *Aust. J. Exp. Agric. Anim. Husb., 13*: 587-592.

BROWN, R. H., and MEAGHER, J. W., 1970. Resistance in cereals to the cyst nematode (*Heterodera avenae*) in Victoria. *Aust. J. Exp. Agric. Anim. Husb., 10*: 360-365.

BROWN, R. H., MEAGHER, J. W. and MCSWAIN, N. K., 1970. Chemical control of the cereal cyst nematode (*Heterodera avenae*) in the Victorian Mallee. *Aust. J. Exp. Agric. Anim. Husb., 10*: 172-173.

HYNES, H. J., 1937. Studies on *Rhizoctonia* root rot of wheat and oats. *Sci. Bull. Dep. Agric. N.S.W. No. 58.*

MEAGHER, J.W. and BROWN, R.H., 1974. Microplot experiments on the effect of plant hosts on populations of the cereal cyst nematode (*Heterodera avenae*) and on the subsequent yield of wheat. *Nematologica, 20*: 337-346.

MEAGHER, J. W. and ROONEY, D.R., 1966. The effect of crop rotations in the Victorian Wimmera on the cereal cyst nematode (*Heterodera avenae*), nitrogen fertility, and wheat yield. *Aust. J. Exp. Agric. Anim. Husb., 6*: 425-431.

MEAGHER, J.W., BROWN, R. H. and ROVIRA, A. D., 1978. The effects of cereal cyst nematode (*Heterodera avenae*) and *Rhizoctonia solani* on the growth and yield of wheat. *Aust. J. Agric. Res., 29*: 1127-1137.

Accepted for publication on 7 October 1981.