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An evaluation of seed-pellet insecticides in a precision drilled crop of sugar beet

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The control of soil pests of sugar beet by means of seed-pellet insecticides was investigated on each of two farms in Co. Wexford from 2000 to 2002. The farms on which trials were conducted differed each season. A number of seed-pellet insecticides were compared with the standard methiocarb seed treatment, methiocarb supplemented with the in-furrow applied granule insecticide carbofuran-isofenphos and with an untreated control. Imidacloprid, Montur and thiamethoxam significantly reduced onychiurid numbers around seedlings compared with the untreated control and significantly reduced pest damage to seedlings compared with the standard methiocarb treatment. Imidacloprid gave best control of pest biting of seedlings and was as effective as the in-furrow incorporated granule insecticide in preventing pest damage and plant mortality at sites having moderate onychiurid infestations. Montur, while less effective than imidacloprid in controlling pest bites on seedling roots, gave consistently good plant establishment. Thiamethoxam was less effective than imidacloprid in some trials at reducing plant damage and mortality. The retardation of seedling growth and establishment recorded for insecticide-propamocarb combinations relative to insecticide-hymexazol combinations in some field and glasshouse trials could be overcome by replacing propamocarb with hymexazol.

Keywords: Insecticide seed treatments; onychiurid; sugar beet

Introduction

The risk of pest damage to sugar beet during the establishment phase of growth is far greater than the corresponding threat to any other arable crop grown in Ireland. The soil pests damaging

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beet include onychiurids, symphylids, millipedes, pygmy beetles and wireworms and the near-surface-active slugs and leatherjackets. While onychiurids are the most widespread soil pest, their damage is seldom severe enough to require the re-sowing of crops. All sugar beet seed purchased by Irish growers, to 2001, included 0.5% methiocarb in the seed pellet. Additionally, at least 60% of crops were also treated with a soil-applied pesticide such as methiocarb molluscicide or granule insecticide. While methiocarb seed treatment can reduce damage to seedling beet by some pests it will not give adequate control of damage where moderate to high pest infestations occur (Dewar, 1988; Kennedy and Connery, 1997). The discovery of nitromethylene insecticides and their guanadine derivatives (Soloway *et al.,* 1978; Elbert *et al.,* 1990, 1991; Senn *et al.,* 1998) offers the prospect of controlling crop pests by applying insecticide as a seed treatment. These seed treatments alone or combined with pyrethroid insecticides can reduce the amount of pesticide active ingredient per unit area by 80 to 96% relative to granule insecticides. Seed treatments have an advantage over other forms of pesticide application in that the active ingredient is placed in the rhizosphere thereby reducing the risk to non-target organisms, reducing the hazard to operators and obviating the need for special applicators (Cooke, 1992). Seed insecticides are also considered to be the most cost effective and environmentally safe way of controlling the most threatening sugar beet pests (Ecclestone, 1997).

The beet seed pellet available in Ireland includes the fungicide propamocarb for the control of seedling diseases caused by *Phytium* and *Aphanomyces*. In Europe, however, hymexazol is used to control these diseases (Dewar and Asher, 1994). Earlier investigations (Kennedy and Connery, 1995) indicated retardation in seedling development due to insecticide-propamocarb combinations relative to insecticide-hymexazol combinations.

The objective of this investigation was to evaluate the control of soil pests and their damage to sugar beet by means of nitromethylene insecticide seed treatments relative to the standard methiocarb seed treatment and the standard treatment supplemented with the granule insecticide carbofuran-isofenphos and an untreated control on farms where soil pests were known to occur. A secondary objective was to investigate the effects of insecticides accompanied by either of two seed fungicides, propamocarb and hymexazol, on seedling establishment.

Materials and Methods

Seed treatments

The control of soil pests of sugar beet by means of insecticide seed treatments was investigated on each of two farms in Co. Wexford, in 2000, 2001 and 2002. Farms previously considered to have pest problems were selected each season. The treatments investigated are given in Table 1. All beet seed was soaked in a suspension of the fungicide thiram prior to pelleting to control seedling diseases. Each pellet-incorporated insecticide was separately evaluated with either the accompanying seed-pellet fungicide propamocarb or hymexazol. Insecticide-untreated seed pellets were also treated with one or other of these fungicides. The standard rates of propamocarb and hymexazol were 14 and 15 g per 10^5 seeds, respectively. One-seed-unit (U) contains 10^5 seeds. The treated seed was provided by Irish Sugar plc.

Table 1. Insecticide treatments used in field trials

Treatment	Insecticide[a]	Active ingredient (g) per 10^5 seeds	Trade name
T1	Imidacloprid	90	Gaucho
T2	Thiamethoxam	45	Cruiser-45
T3	Thiamethoxam	60	Cruiser-60
T4	Imidacloprid + Tefluthrin	15 + 4	Montur
T5	Methiocarb	5	Mesurol
T6	Methiocarb + Carbofuran-isofenphos	5.5[b]	Yaltox-combi
Control	None	Nil	-

[a]All insecticides except carbofuran-isofenphos were incorporated in the seed pellet. Carbofuran-isofenphos was applied with an applicator attached to the seeder.
[b]Applied as granules at 5.5 kg/ha.

Experimental design

The design of each trial was a randomised block with four or six replicates per treatment. Each replicate consisted of five rows 10 m long and 0.58 m apart. Soil cores taken for pest investigations were 15 cm deep and 6.4 cm diameter. The cultivar Zulu was grown in 2000 and Libra in 2001 and 2002. The effects of insecticide seed treatments combined with either the fungicide propamocarb or hymexazol on seedling establishment was also measured in the glasshouse. Trays (21 cm × 36 cm × 5 cm) of sterile soil were each sown with 50 seeds. Glasshouse trials were replicated four times. After 7 weeks growth, seedling numbers were recorded. In 2000 all treatments sown in the field were assessed in the glasshouse for seedling emergence. In 2001 and 2002 the treatments investigated in the glasshouse were imidacloprid at 0.67, 1.0 and 1.5 times the standard rate (90 g/U) in combination with either 0.5, 1.0, 1.5 and 2.0 times the standard rate (14 g/U) of propamocarb. Additionally beet seed treated with thiamethoxam-45, thiamethoxam-60, Montur or methiocarb were each investigated with standard rate propamocarb. Similar investigations of insecticides with hymexazol at the above rates were undertaken.

Seedling weight

The effects of insecticides, combined with either of the pellet-incorporated fungicides propamocarb or hymexazol, on seedling weight at the 8-leaf stage of growth were recorded. Three seedlings, growing consecutively, were collected at each of four locations per plot. These locations, on each of the two outer drills, were 3.3 m from either end of plots. Plants were dried in a hot-air oven for 24 h at 90 °C.

Pest assessments

The efficacy of seed treatments in controlling pests and their damage was compared with the standard methiocarb seed treatment, methiocarb treated seed supplemented with the furrow incorporated granule insecticide carbofuran-isofenphos and with insecticide untreated seed. The efficacy parameters were: *(i)* number of soil pests in the vicinity of seedlings at the 6- to 8-leaf stage of growth; *(ii)* the number of pest bites per seedling and *(iii)* plant establishment at the 8-leaf stage, based on plant counts from the three centre drills of each plot. The pest infestation was measured by examining five soil core samples per plot. Each sample included a beet plant that was examined for pest damage. Beet pests were identified using the following keys: Collembola, Gisin (1960); symphylids, Edwards (1959);

millipedes, Blower (1958); pygmy beetles, Joy (1932) and tipulids, Brindle (1960).

Data analysis

Results were analysed using analysis of variance procedures. Means were compared using the least significance difference (LSD) method. All seed treatments investigated in glasshouse trials were compared by transforming the data [arc-sine/square root (GenStat Release 9.1)] and analysing by ANOVA. Plant establishment data from field trials was not transformed since the variance was approximately constant.

Results

Soil pests

Onychiurus armatus (onychiurid) comprised 90% of the pests recorded in soil samples from the six trials undertaken (Table 2). The remaining pest infestations were *Scutigerella immaculata* (Newport) (symphylid) 5.8%, *Blaniulus guttulatus* (Bosc) (spotted snake millipede) 2.1% and *Atomaria linearis* (Stephens) pygmy beetle 2.1%. With the exception of Trial 2 in 2000 all trials had potentially injurious onychiurid infestations. Results from Trial 2 are omitted due to low pest numbers and damage to seedlings. Only in Trial 1, in 2000, did insecticide treatments significantly reduce pest numbers around seedlings (Table 3). In this trial the four pellet insecticides (imidacloprid, thiamethoxam-45, thiamethoxam-60 and Montur) had lower numbers of onychiurids around seedlings compared with the untreated control and these differences were significant for thiamethoxam-45, thiamethoxam-60 and Montur. They also had lower numbers of

Table 2. The number of pests per soil sample from plots of insecticide untreated beet. Each soil sample included a beet seedling at the 6- to 8-leaf stage of growth

Trial	Year	Pest			
		Onychiurids	Symphylids	Millipedes	Pygmy beetles
1	2000	9.3	0.35	0.1	0.0
2	2000	0.15	0.7	0.35	0.0
3	2001	6.2	1.37	0.5	0.93
4	2001	10.6	0.20	0.05	0.20
5	2002	17.6	0.60	0.20	0.0
6	2002	8.7	0.16	0.04	0.1

Table 3. The effect of insecticide seed treatment on the number of onychiurids per soil sample around beet seedlings at 6–8 leaf stage of growth

Treatment[a]	Trial[b]				
	1	3	4	5	6
T1[a]	6.0	5.8	6.7	14.8	8.9
T2	5.1	7.6	6.9	19.0	10.3
T3	3.4	6.5	7.8	20.6	10.6
T4	5.5	7.3	9.3	21.7	9.4
T5	8.1	8.6	5.8	14.3	8.8
T6	2.9	6.2	5.6	19.6	7.4
Control	9.3	6.2	10.6	17.6	8.7
s.e.d.	1.742	1.911	1.855	3.579	2.877
Significance	*				

[a]Treatments listed in Table 1.

[b]Trial 2 results omitted due to low pest numbers.

onychiurids compared with the standard methiocarb treatment but the difference was significant only for thiamethoxam-60. The four pellet insecticides had greater numbers of onychiurids around seedlings compared with the methiocarb plus granule insecticide combination but the differences were not significant.

Pest bites per seedling

The number of bites on seedling roots/hypocotyls, was recorded in five of the six trials investigated. Significant reduction in the number of bites per seedling, relative to those for untreated seed, was recorded for imidacloprid, thiamethoxam-45, thiamethoxam-60, Montur, methiocarb and methiocarb plus carbofuran-isofenphos granules in 5, 5, 4, 4, 2 and 4 trials, respectively (Table 4). Overall, the imidacloprid seed treatment had fewest pest bites followed by the treatment involving the granule insecticide (Figure 1). The standard methiocarb treatment was least effective

Table 4. The effect of insecticide seed treatment on the number of onychiurid bites per sugar beet seedling at 6–8 leaf stage of growth

Treatment[a]	Trial[b]				
	1	3	4	5	6
T1	3.8	2.1	2.1	3.2	1.8
T2	5.6	3.7	2.4	11.6	2.5
T3	7.0	3.5	4.2	11.8	3.7
T4	5.8	3.4	5.2	8.8	2.3
T5	8.3	7.8	3.3	15.6	5.0
T6	3.2	4.2	2.6	4.9	3.8
Control	14.5	8.9	7.8	19.0	5.1
LSD (5%)	5.16	2.64	3.02	6.54	2.03

[a]Treatments listed in Table 1.
[b]Trial 2 results omitted due to low pest numbers.

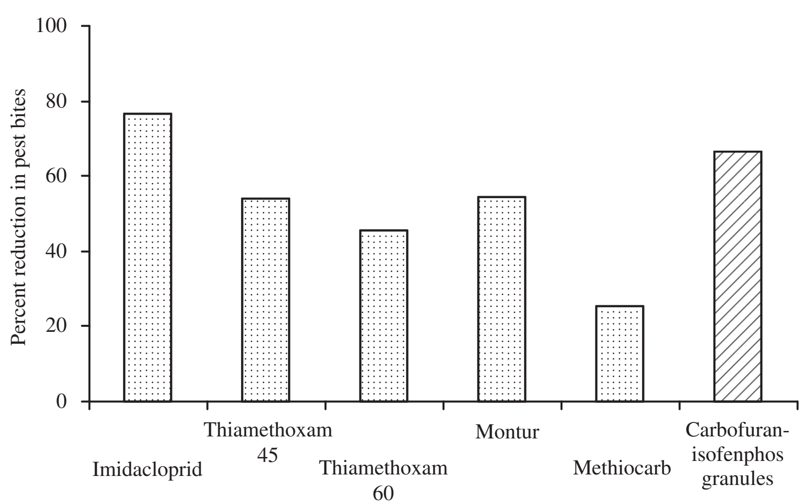

Figure 1. Average percent reduction in the number of pest bites per seedling root/hypocotyl for seed treatments and insecticide granule treatment, relative to untreated plots.

in controlling pest damage. Imidacloprid, thiamethoxam-45, thiamethoxam-60 and Montur had significantly fewer pest bites/ seedling relative to the standard methiocarb treatment in 3, 2, 1 and 3 trials, respectively. Methiocarb had more bites/ seedling in all six trials relative to the methiocarb plus granule insecticide treatment and the difference was significant for two trials. While imidacloprid, thiamethoxam-45, thiamethoxam-60 and Montur had fewer bites/seedling than granule insecticide treated plots in 4, 3, 3 and 2 trials, respectively, these differences were not significant.

Plant establishment

The values for percent plant establishment recorded for each treatment in each of the five trials in which pests occurred are given in Table 5. The mean percent plant establishment over the six trials for the treatments imidacloprid, thiamethoxam-45, thiamethoxam-60, Montur, methiocarb, methiocarb plus granule insecticide and untreated control were 79.0, 72.3, 75.0, 77.5, 70.4, 75.9 and 69.8, respectively. Compared to untreated control Montur had significantly higher establishment in four trials, imidacloprid in three trials, thiamethoxam-45 in two and thiamethoxam-60 and methiocarb plus granule insecticide in one trial each. The standard methiocarb did not significantly improve plant establishment relative to that for untreated plots and mean values were similar. Comparisons with standard methiocarb treatment showed that imidacloprid had a greater plant establishment in all six trials and this difference was significant in three cases. The treatments thiamethoxam-45, thiamethoxam-60, Montur and methiocarb plus granule insecticide had greater plant establishment relative to methiocarb in 3, 5, 5, and 5 trials, respectively. The increase in establishment was significant in 1, 2, 4 and 1 trial, respectively. Comparing plant establishment for seed treatments with that for methiocarb plus granule insecticide showed that overall imidacloprid and Montur had highest establishment values. However, only in the case of two treatments, Montur and thiamethoxam-45 was plant establishment significantly greater when compared with that for the methiocarb plus granule insecticide.

Comparison of pellet insecticides with either propamocarb or hymexazol fungicide

Pest numbers per soil sample, pest bites per seedling and percent plant establishment for insecticide-propamocarb combinations were similar to those for insecticide-

Table 5. The effect of insecticide seed treatment on percent plant establishment

Treatment[a]	Trial[b]				
	1	3	4	5	6
T1	75.7	76.4	86.2	87.2	75.0
T2	56.1	78.9	80.7	89.7	66.3
T3	63.8	75.0	86.7	86.2	69.8
T4	73.3	76.4	84.2	88.2	77.6
T5	57.6	65.7	76.6	85.2	67.3
T6	67.7	75.7	81.0	83.1	69.7
Control	57.6	64.4	82.3	82.7	64.3
LSD (5%)	12.97	9.16	5.70	4.62	8.26

[a]Treatments listed in Table 1.
[b]Trial 2 results omitted due to low pest numbers.

hymexazol combinations. However, the dry weight of seedlings, collected at the 8-leaf stage of growth was significantly lower for insecticide-propamocarb combinations relative to insecticide-hymexazol combinations in two of the six trials.

Glasshouse investigations in 2000 showed that percent plant establishment for imidacloprid 90 and thiamethoxam-45 and -60 were marginally lower when used with the fungicide propamocarb than when used with hymexazol. The percent plant establishment for beet treated with insecticides at various rates and with various rates of either the fungicide propamocarb or hymexazol in glasshouse trials in 2001 are given in Table 6. The two higher rates of imidacloprid (90 and 135 g) and the two rates of thiamethoxam (45 and 60 g) used in combination with propamocarb had significantly lower plant establishment when compared with standard seed (methiocarb 5 g + propamocarb 14 g). The percent plant establishment for these insecticides and the fungicide hymexazol were not significantly reduced when compared with seed treated with the standard rates of hymexazol (15 g) and methiocarb. Reducing propamocarb to half or increasing it to twice the standard rate, when used with imidacloprid, had little influence in altering the percent

Table 6. Mean values for arcsin√ transform of percent plant establishment for each combination of insecticide and fungicide treatment (glasshouse trial 2001)

Insecticide treatment		Fungicide level	Fungicide	
Insecticide	Rate (g) per 10^5 seeds	(relative to standard rate[1])	Propamocarb	Hymexazol
Imidacloprid	60	0.5	1.286 (92.0)[2]	1.238 (89.0)
	60	1.0	1.324 (93.5)	1.309 (90.5)
	60	1.5	1.419 (96.5)	1.351 (95.0)
	60	2.0	1.281 (91.0)	1.305 (91.0)
	90	0.5	1.114* (80.5)	1.360 (94.0)
	90	1.0	1.116* (80.0)	1.227 (88.5)
	90	1.5	1.084* (78.0)	1.410 (95.0)
	90	2.0	1.132* (81.0)	1.292 (91.5)
	135	0.5	1.141* (82.0)	1.320 (93.5)
	135	1.0	1.220* (87.5)	1.384 (94.0)
	135	1.5	1.097* (79.0)	1.184 (85.5)
	135	2.0	1.098* (79.0)	1.369 (93.5)
Thiamethoxam	45	1.0	1.121* (80.5)	1.228 (88.0)
	60	1.0	1.071* (77.0)	1.242 (89.0)
Montur[3]	15 + 4	1.0	1.274 (90.0)	1.316 (91.5)
Methiocarb	5	1.0	1.378 (95.0)	1.375 (94.5)
LSD (5%)	–	–	0.151	–

*Significantly different from methiocarb combined with either propamocarb or hymexazol.
[1]The standard rate of propamocarb was 14 g active ingredient per 10^5 seeds and the corresponding value for hymexazol was 15 g per 10^5 seeds.
[2]Percent scale from back-transformed arcsin√ values.
[3]Montur = imidacloprid (15 g) + tefluthrin (4 g).

plant establishment. Reducing the rate of imidacloprid to 2/3 the standard rate when used with propamocarb prevented a significant reduction in plant establishment. In 2001, the mean plant establishment for all insecticide treatments used with the fungicide propamocarb was 85.1% compared with 91.5% for these insecticides used with hymexazol and this difference was significant.

In 2002, the percent plant establishment for standard seed was 96.5%. Twelve of the 15 insecticides rates used in combination with propamocarb had plant establishment values that were significantly lower than that for standard seed (Table 7). The three treatments not differing significantly were imidacloprid 60 g and 135 g + ½ rate propamocarb and imidacloprid 90 g with normal rate propamocarb. The percent plant establishment for insecticides used with the fungicide hymexazol showed that five treatments, imidacloprid 135 g + standard rate hymexazol, imidacloprid 60 g + 1½ rate hymexazol and imidacloprid 60 g, 90 g and 135 g + 2 rate hymexazol had significantly fewer plants than the standard rate of hymexazol (15 g) and methiocarb. The mean plant establishment for all insecticides used with the fungicide propamocarb, in 2002, was 90.5%. The corresponding value for these insecticides used with hymexazol did not differ significantly (89.1%).

Table 7. Mean values for arcsin√ transform of percent plant establishment for each combination of insecticide and fungicide treatment (glasshouse trial 2002)

Insecticide treatment		Fungicide level (relative to standard rate[1])	Fungicide	
Insecticide	Rate (g) per 10^5 seeds		Propamocarb	Hymexazol
Imidacloprid	60	0.5	1.349 (93.0)[2]	1.228 (87.5)
	60	1.0	1.252* (90.0)	1.264 (90.0)
	60	1.5	1.247* (89.0)	1.172* (84.5)
	60	2.0	1.218* (88.0)	1.116* (80.0)
	90	0.5	1.212* (87.5)	1.310 (93.0)
	90	1.0	1.335 (94.5)	1.408 (96.5)
	90	1.5	1.268* (91.0)	1.280 (91.5)
	90	2.0	1.285* (92.0)	1.111* (80.0)
	135	0.5	1.313 (93.0)	1.250 (90)
	135	1.0	1.282* (91.5)	1.182* (85.5)
	135	1.5	1.257* (90.0)	1.242 (89.5)
	135	2.0	1.187* (85.5)	1.211* (87.0)
Thiamethoxam	45	1.0	1.246* (89.5)	1.311 (91)
	60	1.0	1.229* (88.5)	1.236 (89.0)
Montur[3]	15 + 4	1.0	1.174* (84.5)	1.263 (90.5)
Methiocarb	5	1.0	1.413 (96.5)	1.369 (93.5)
LSD (5%)	-	-	0.123	0.150

*Significantly different from methiocarb combined with either propamocarb or hymexazol.
[1]The standard rate of propamocarb was 14 g active ingredient per 10^5 seeds and the corresponding value for hymexazol was 15 g per 10^5 seeds.
[2]Percent scale from back-transformed arcsin√ values.
[3]Montur = imidacloprid (15 g) + tefluthrin (4 g).

Discussion

Onychiurids were the dominant pest in these trials and are considered the most widespread and important of the soil pests of sugar beet in Ireland (Kennedy and Connery, 1997). The latter workers reported a positive relationship between soil pest numbers in the vicinity of beet seedlings and the prevalence of bites on roots together with a negative relationship with plant density. The low number of pests in the granule insecticide plots in Trial 1, 2000, the only trial in which pest numbers were significantly reduced by treatments, was anticipated based on earlier investigations with granule insecticides. The absence of a pest reducing effect for granules in 2001 and 2002 was surprising and may have been due to the late migration of pests to the root zone. The examination of seedling roots, particularly in 2002, indicated pest biting occurred just prior to sampling at the 6 to 8-leaf stage of growth. Normally onychiurids and other soil pests aggregate around newly germinated seedlings on which they feed leaving small rounded holes or bites causing lethal and sub-lethal damage resulting in yield loss (Brown, 1985; Cooke, 1992). Trial 1 2000 also showed that while pellet incorporated insecticides can significantly reduce soil pests in the root zone they are less effective in this regard than the granule insecticide.

Imidacloprid and Montur were as effective as the granule insecticide in controlling pest damage whereas thiamethoxam-45 and thiamethoxam-60 had significantly more bites relative to the granule treatment in Trial 1, 2000. When compared with the standard methiocarb seed treatment which is applied to 90% of beet seed sown in Ireland, imidacloprid and Montur seed treatments gave significantly better control of pest bites in three of the five trials having soil pests. While overall imidacloprid had fewer bites/seedling than Montur the level of control of biting by the latter, which contains only one sixth the amount of active ingredient of the former together with a moderate rate of tefluthrin, was not anticipated. In earlier trials involving tefluthrin as both seed and fine-granule treatments poor control of soil pest numbers and seedling bites were recorded but nevertheless significant improvements in plant establishment numbers relative to untreated seed was achieved. While plant mortality generally increases with increasing number of bites per seedling, sometimes seedlings may have a considerable number of bites, as in 2002, without extensive reduction in plant populations occurring. Such sub-lethal pest ‘grazing’ on seedlings was suggested by Dewar (1996) to account for the lower than model-predicted plot yields, in UK trials, as based on plant populations. The ability of an insecticide to reduce pest feeding on seedlings in addition to preventing seedling mortality is therefore an important attribute of an insecticide and in this regard imidacloprid was best in these trials.

The seed treatments imidacloprid and Montur had non-significantly higher and thiamethoxam-60 rather similar plant establishment to that for the granule insecticide. This suggests that for moderate infestations imidacloprid, Montur and thiamethoxam-60 are as effective as the granule insecticide in controlling soil pest damage. From a growers viewpoint seed pellet incorporated insecticides are a more convenient and less hazardous means of controlling pest problems than using granule insecticides. In Britain, imidacloprid was also found to give equal or better control of pest damage to beet than that provided by granule insecticide (Ecclestone, 1997). Where soil pest damage to beet was extremely severe in The

Netherlands (Heijbroek and Huijbregts, 1995) carbofuran granules were found to give better control of damage than various seed pellet insecticides, including imidacloprid. Similar findings were obtained from a series of trials across Europe (Hermann, Wauters and Dewar, 2001) in which carbofuran granules had a greater efficacy than imidacloprid where severe pest attacks occurred particularly by high infestations of onychiurids and millipedes. Montur which is a mixture of 15 g imidacloprid and 4 g tefluthrin had a similar plant establishment to the commercially available rate of imidacloprid at 90 g per seed unit. While the latter result was unexpected in 2000 it was corroborated in 2001 and 2002. Imidacloprid has a distinct advantage over Montur in the control of foliage pests such as aphids (Dewar *et al.,* 2000) and capsids (personal observations). This could be expected since the higher rate of imidacloprid which is systemic (Elbert *et al.,* 1991) would be likely to give better control of foliage pests than Montur which contains a low rate of imidacloprid and the non-systemic (Gruenholz, Gallardo and Mesanza, 1986) tefluthrin. The addition of tefluthrin or other pyrethroid to insecticides such as imidacloprid and thiamethoxam broadens their spectrum of activity and improves plant establishment (Dewar, Haylock and Garner, 2004). A similar response was reported by Hermann (2004) for the control of wireworm and leatherjackets in beet. Dewar *et al.* (2000) reported that mixtures of tefluthrin and imidacloprid applied to pelleted seed of sugar beet gave consistently better control of soil pests including onychiurids compared with each insecticide alone. They also reported that thiamethoxam which gave moderate control of soil pests when applied alone performed better when mixed with tefluthrin. However, Hermann *et al.* (2001) warn that some pest problems such as wireworms, leatherjackets and onychiurids cannot be controlled only with insecticide seed treatments. Even with the addition of tefluthrin to imidacloprid and thiamethoxam they recommend the seed treatments should generally be complemented by other types of insecticide treatments such as presowing-spraying or microgranules. Large infestations of soil pests in the beet growing areas of Ireland are not common; the more usual problems are moderate infestations of soil pests of which onychiurids are the most common and which could be effectively controlled by the seed treatment imidacloprid.

In these and earlier trials, methiocarb provided reductions in both soil pest numbers around seedlings and pest bites on seedlings but only infrequently prevented significant reductions in plant mortality by soil pests. In a large number of trials in the UK, Dewar (1988) recorded similar plant establishment for methiocarb and untreated seed and concluded methiocarb conferred little or no benefit to seedlings. Methiocarb was withdrawn from use as a seed pellet insecticide in the UK in 1995 (Ecclestone and Fisher, 1997). The somewhat better control of soil pest damage by methiocarb in Ireland compared with that in Britain is probably due to the rate of application of 0.5% and 0.2%, respectively. The lower rate in Britain was adopted to avoid possible phytotoxic effects (Dewar, 1988) but no such adverse effects were recorded or are anticipated for the higher rate of methiocarb applied to Irish beet seed.

The weight of seedlings from some field trials, at the 8-leaf stage of growth, showed combinations of either imidacloprid or thiamethoxam and the fungicide propamocarb were less than seedling weights from seed treated with these insecticides and the fungicide hymexazol.

This weight difference confirmed an inhibitory effect on plant development by insecticide-propamocarb combinations. No evidence of seedling mortality due to imidacloprid/thiamethoxam-propamocarb combinations in field trials was observed. Glasshouse investigations on retardation of seedling development corroborated those in the field. Plant establishment was reduced when imidacloprid and thiamethoxam were used with propamocarb relative to those insecticides with hymexazol in 2001 but not in 2002. In other trials at Oak Park, imidacloprid alone was found to cause slight delays in emergence and establishment when compared with methiocarb treated seed. However, differences usually had disappeared by the 10-leaf stage of growth and in the absence of soil pests root and sugar yields were unaffected. Hymexazol and not propamocarb is the seed pellet fungicide of choice in the UK and Europe to control soil-borne beet seedling pathogens and could be used in Ireland to avoid the inhibitory effects recorded for insecticide-propamocarb combinations. A reduced speed of seedling emergence was found for imidacloprid treated seed in the UK (Ecclestone, 1997) relative to methiocarb treated seed but final plant establishments were not significantly reduced. In collaborative trials in Europe, imidacloprid showed a delay of some days in plant establishment (Wauters and Dewar, 1995); the most pronounced effects were recorded in the Mediterranean area when the product was used at 90 g/U. In more recent trials across Europe, Hermann *et al.* (2001) reported delayed emergence for imidacloprid and thiamethoxam treated seed in situations where there was an absence of pests. Phytotoxic interactions involving imidacloprid and thiamethoxam and the herbicide lenacil have been noted in the UK (Dewar *et al.,* 2003).

It is concluded that imidacloprid is as effective as the granule insecticide carbofuran-isofenphos in controlling pest damage and plant mortality to beet at sites having moderate onychiurid infestations. The standard methiocarb seed treatment could be replaced by imidacloprid which is significantly better at controlling pest damage. Montur, while providing similar plant establishment to imidacloprid, is less effective in controlling pest numbers in the vicinity of seedlings and pest bites on seedling roots. Other observations, at Oak Park, have shown imidacloprid to give reasonable control of capsid and leatherjacket damage to seedling beet. The retardation of seedling development recorded in fields could be overcome by replacing the seed pellet incorporated fungicide propamocarb with hymexazol. The control of soil pests by seed-pellet insecticides in precision-sown beet together with their observed and known control of foliage pests suggests seed-pellet insecticides could also be expected to control pest damage of other precision-sown crops.

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