Final Report

Provision of Information on Varietal Tolerance and Resistance to *Globodera pallida*

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CONTENTS

1. SUMMARY

Varietal Tolerance to Potato Cyst Nematodes (PCN): The level of tolerance attributed to a potato cultivar indicates its capacity to deliver a commercially viable yield in spite of the damage and drain on nutrients brought about by a population of PCN.

Varietal Resistance to PCN: The level of resistance in a cultivar indicates its facility for reducing the potential for nematode multiplication. For example, full resistance to *Globodera rostochiensis* means there is no multiplication; whereas partial resistance to *Globodera* pallida means that there is some, but limited, multiplication

Where there is a moderate to high level of tolerance but no resistance, the crop is able to successfully grow and develop but the nematodes will multiply, leaving a legacy of elevated levels of PCN.

Assessment of Tolerance
Tolerance to PCN can be assessed using pot/glasshouse trials. However, extrapolation of tolerance from pot data to a field grown crop is far more difficult compared to field-based data. A field-based method to determine varietal tolerance to PCN was successfully developed in a previous Potato Council-funded project (R264 Assessment of varietal tolerance to potato cyst nematode damage). The project final report, written by John Keer, was published in 2007. It provided information on the tolerance of some of the widely grown GB varieties and the information was subsequently incorporated into the PCN model provided by Potato Council http://www.potato.org.uk/online-toolbox/pcn-calculator However, the number of varieties that can be assessed using the field-based method is limited and many newer varieties still remained to be evaluated. This project, commissioned by Potato Council in 2010, was designed to add tolerance information for a range of the newer varieties. Resistance to PCN is another very important agronomic trait and some of the varieties in this project were chosen for their claimed resistance to *Globodera pallida.*

Potato varieties were grown in an untreated area and in an adjacent nematicide-treated area. Yields from the treated and untreated areas were compared to provide a relative ranking of PCN tolerance for the varieties. The results allow the varieties to be positioned according to potential yield loss and initial PCN infestation level. The varieties Maris Peer (very intolerant) and Cara (very tolerant) were used in the trial as "standards" for PCN tolerance, based on previous findings (see R264 Final Report).

The work described in this report was carried out using the same protocol at a different, single site in 2010, 2011 and 2012, respectively. Only *G. pallida* infested sites were chosen, to examine the effect of claimed *G. pallida* resistance of some of the varieties.

The 2010 trial was sited at Spalding, Lincolnshire on a fine sandy silt loam. This was an un-irrigated site with a *G. pallida* population of 14-17 eggs/g soil.

The 2011 trial was sited at Gosberton, Lincolnshire on a silt loam. This was an un-irrigated site with a *G. pallida* population of 9-14 eggs/g soil.

The 2012 trial was at Aylsham, Norfolk on a sandy loam. This was an irrigated site with a *G. pallida* population of 16-23 eggs/g soil.

Results: Tolerance

The table below summarises the % yield loss for each variety in each trial (year). The values are calculated from the average total yield (t/ha) in the untreated and vydate treated plots:

% yield loss = 100-((yield in untreated plots/yield in vydate treated plots)*100)

The yield loss has been ranked within each trial and the values are provided in brackets in italics alongside the % yield loss values (rank 1 = the greatest yield loss).

Variety	**% yield loss**		
	2010	**2011**	**2012**
Cabaret	33 *(3)*	-3 *(14)*	7 *(7)*
Cara	-1 *(14)*	6 *(8)*	14 *(1)*
Chicago	14 *(8)*	-1 *(13)*	14 *(1)*
Desiree	2 *(12)*	4 *(10)*	12 *(3)*
Harmony	36 *(1)*	12 *(6)*	6 *(8)*
Innovator	22 *(5)*	6 *(8)*	4 *(10)*
Jelly	23 *(4)*	1 *(11)*	-2 *(13)*
Maris Peer	35 *(2)*	25 *(1)*	12 *(3)*
Markies	8 *(10)*	13 *(4)*	9 *(6)*
Melody	19 *(6)*	15 *(3)*	6 *(8)*
Sapphire	1 *(13)*	1 *(11)*	11 *(5)*
Saxon	13 *(9)*	17 *(2)*	2 *(12)*
Sierra Gold	5 *(11)*	13 *(4)*	n/a
Vales Everest	16 *(7)*	7 *(7)*	4 *(10)*

Cara was included as a benchmark or “standard” tolerant variety which normally shows similar yields irrespective of whether a nematicide is used. In contrast, Maris Peer was included as a “standard” intolerant variety which normally shows large yield increases when a nematicide is used. It is clear that there were major differences in the performance of the varieties over the three years.

2010

The weather during the 2010 growing season could be described as average for south Lincolnshire. The “standard” varieties for PCN tolerance behaved in line with expectation. Maris Peer showed a large yield increase due to the nematicidal control of PCN, whereas the Cara yield was almost unaffected by nematicide use. (A value of -1 indicates that the average yield in the untreated plots was slightly higher than the average yield in the vydate-treated plots. The average yields were 68.2 and 67.6 t/ha, respectively). Harmony and Cabaret also showed big yield increases due to PCN control and would be described as very intolerant. The varieties Jelly, Melody, Innovator, Vales Everest, Chicago Saxon and Markies all showed intermediate yield responses to nematicide use and would be classed as intolerant. Sierra Gold, Desiree and Sapphire all gave the least response to nematicide and would be described as tolerant.

2011

2011 was one of the driest growing seasons on record. Such severely dry conditions would be expected to greatly affect the interaction between the crop, PCN and

nematicide control. A nematicide relies on sufficient soil water to dissolve the active ingredient and prevent PCN juveniles from affecting potato root systems. Therefore the yield differences between nematicide-treated and untreated crops are likely to be reduced due to impaired nematicide activity. Largely as a consequence of the unusual weather conditions, there was little difference between the tolerances of the different varieties. Some varieties, particularly Cabaret and Jelly, performed very differently compared to the 2010 season. Because weather conditions masked tolerance differences in 2011 it was not possible to assign tolerance classes from 2011 data.

2012

The weather conditions of 2012 were also very extreme. This season was one of the wettest on record. Abnormally wet conditions also affect the interaction between crop, PCN and nematicide control. Continually wet soil conditions can cause leaching of nematicide with a consequent reduction in efficacy. Poor nematicide efficacy will mask the effect of varietal tolerance. To further complicate interpretation of tolerance data, light levels were exceptionally low which resulted in low yields across all varieties. Low light levels became the yield-limiting factor, rather than PCN damage. Unfortunately, these extreme weather conditions resulted in atypical performance of the "standard" varieties which greatly diminished the reliability of 2012 tolerance data.

Given the variability in performance of the varieties across the three years it has not been possible to assign tolerance categories to the newer varieties. As a result, the PCN calculator provided by Potato Council http://www.potato.org.uk/online-toolbox/pcn-calculator has not been updated as originally intended. Alternative methods to assess tolerance are available, for example, pot tests to measure the effects of PCN infestation on root biomass. Results from pot tests have been shown to be consistent with field-based methods to assess tolerance (e.g., Arntzen & Wouters, 1994) and in future it may be necessary to carry out pot tests, in addition to field-based assessments, so that the pot test results are available to help interpret the field-based observations.

Resistance

Although extreme weather conditions during the 2011 and 2012 seasons seriously affected tolerance data, good consistent PCN population dynamics data was obtained from trials across all three seasons. When Innovator, Harmony and Vales Everest were grown in conjunction with a nematicide, a decrease in *G. pallida* levels was observed in all trials over the 2010 – 2012 period. Even where these varieties were grown in the absence of nematicides, *G. pallida* levels were either reduced or remained at pre-growing levels.

Resistance to *G. pallida* is evaluated as part of National List testing in GB. Tubers are planted in pots in compost infected with a standard concentration of PCN eggs and cyst multiplication on roots is assessed. The results are used to calculate resistance on a 1-9 scale (low values = susceptibility to *G. pallida*).The ratings are available at http://varieties.potato.org.uk/menu.php

Some of the varieties included in this project have already been evaluated for resistance to PCN using the National List method and their 1-9 ratings are provided below. For the other varieties there are no National List ratings currently available. Although the methods used in this study differ from the National List tests, the ratings generated from the data collected during this project are broadly similar to the National

List ratings. Therefore, the ratings (in bold) generated from this project give a representative indication of the relative resistance to PCN for those varieties where National List ratings are currently not available.

Variety	National List rating*	Rating calculated from field data 2010	Rating calculated from field data 2011	Rating calculated from field data 2012
Maris Peer	2	3	4	2
Cara	2	2	3	1
Vales Everest	6	6	6	5
Innovator	n/a	**9**	**8**	**5**
Desiree	2	2	2	2
Chicago	4	6	4	3
Sierra Gold	n/a	**4**	**3**	Not entered in 2012
Jelly	n/a	**2**	**3**	**3**
Saxon	2	3	3	3
Sapphire	n/a	**3**	**3**	**2**
Markies	2	2	3	2
Melody	2	3	3	2
Cabaret	2	3	3	3
Harmony	4	6	6	3

*Susceptibility/Resistance to *G. pallida* on 1-9 scale. Results from pot studies. n/a ratings not currently available

The finding that some varieties can result in a reduction in *G. pallida* levels has huge implications for future PCN management, especially if nematicide use is curtailed by regulation. The “holy grail” of sustainable PCN management would be to develop varieties with good resistance and tolerance levels. Some new varieties are claiming this combination of traits. Future work should concentrate on evaluating these varieties. This line of development work is especially important, given the regulatory doubts surrounding future nematicide use.

2. INTRODUCTION

It is known that some potato varieties can yield better than other varieties in PCN infested soil. This tolerance to PCN has not been evaluated for many of the newly introduced varieties. Varietal tolerance information would be of great practical benefit to potato growers in PCN infested areas, allowing varieties to be positioned according to potential yield loss and initial PCN infestation level. Varietal tolerance and resistance to PCN are often misunderstood by the potato industry.

Varietal Tolerance to PCN: The level of tolerance attributed to a potato cultivar indicates its capacity to deliver a commercially viable yield in spite of the damage and drain on nutrients brought about by a population of PCN.

Varietal Resistance to PCN: The level of resistance in a cultivar indicates its facility for reducing the potential for nematode multiplication. For example, full resistance to *Globodera rostochiensis* means there is no multiplication; whereas partial resistance to *Globodera* pallida means that there is some but limited multiplication

Resistant varieties may be very intolerant of PCN and highly tolerant varieties often show almost no resistance to PCN.

Variety work on PCN resistance and tolerance traits has previously been assessed by pot growing methods. This methodology can be expensive and difficult to relate to the outside, field-grown crop. Work undertaken earlier, successfully evaluated a field-based method for comparing the tolerance of potato varieties. The field-based method relies on finding an area of exceptionally uniform PCN infestation. Varieties are then grown in an untreated area and in an adjacent, nematicide treated area. Untreated versus treated yields are compared to assess tolerance. Initial PCN levels are compared with post-cropping levels to assess the impact of variety on PCN population dynamics (PCN resistance). Absolute tolerance data is not obtained using this method because the yield from PCN-free soil is not available. Instead, yield will be compared from nematicide treated and untreated plots to provide a relative ranking of the PCN tolerance for a range of varieties. The varieties Cara and Maris Peer are included to validate the trial, and as “standard” varieties for high and low tolerance, respectively.

2.1. Objectives

- To compare a range of newer potato varieties in terms of their tolerance to PCN damage.
- To compare a range of newer potato varieties in terms of their resistance to PCN.

3. MATERIALS AND METHODS

3.1. 2010 Trial

Co-operator: Lincolnshire Field Products Ltd.
Site: Pinchbeck, Spalding
Grid reference: TF 272276
Soil type: Fine sandy loam
Previous crop (2009): Brassicas

Crop & Cultivar: Potato – 14 varieties were planted at 20cm spacing. Tightly graded seed (35-45mm) of a similar physiological age was planted.

Planting Date: 13.04.2010

Field Preparation: Mouldboard plough (winter)
Power harrow
Basalier bedtiller (to incorporate nematicide)
Planter – to form ridges only.
Hand plant.

Plot Maintenance Late blight, weed and insect control consistent with good local practice.

Previous treatments: Nil

Plot size: 1 row X 3m

Design: RCB – first block not randomised. Three replicates.

TABLE 1 - TREATMENT LIST

	Treatment	Rate / ha	Timing
1	Maris Peer		
1a	Maris Peer + Vydate	55kg/ha	Pre-planting
2	Cara		
2a	Cara + Vydate	55kg/ha	Pre-planting
3	Vales Everest		
3a	Vales Everest + Vydate	55kg/ha	Pre-planting
4	Innovator		
4a	Innovator + Vydate	55kg/ha	Pre-planting
5	Desiree		
5a	Desiree + Vydate	55kg/ha	Pre-planting
6	Chicago		
6a	Chicago + Vydate	55kg/ha	Pre-planting
7	Sierra Gold		
7a	Sierra Gold + Vydate	55kg/ha	Pre-planting
8	Jelly		
8a	Jelly + Vydate	55kg/ha	Pre-planting
9	Saxon		
9a	Saxon + Vydate	55kg/ha	Pre-planting
10	Sapphire		
10a	Sapphire + Vydate	55kg/ha	Pre-planting
11	Markies		
11a	Markies + Vydate	55kg/ha	Pre-planting
12	Melody		
12a	Melody + Vydate	55kg/ha	Pre-planting
13	Cabaret		
13a	Cabaret + Vydate	55kg/ha	Pre-planting
14	Harmony		
14a	Harmony + Vydate	55kg/ha	Pre-planting

TABLE 1A - PRODUCT LIST

Product	Active Ingredient	g/l or kg	Formulation	Batch Number
Vydate	oxamyl	10% w/w	GR	MAY09CE131

3.1.1. Application Details

Nematicide granules were broadcast evenly over the ploughed soil surface using a Maxi-cast nematicide granule applicator. Granules were then immediately incorporated into the top 15cm soil using a Basalier bedtiller, prior to planting.

T1

Date:	08.04.2010
Crop Stage:	Pre-planting – five days prior to hand planting.
Crop Cover:	n/a
Leaf Moisture:	n/a
Soil Moisture (Surface):	Damp
Soil Moisture (Sub-surface):	Moist
Soil Condition:	Loose
Soil Tilth:	Fine

Weather at application	
Air temperature (Deg. C):	12
Soil temperature (Deg. C):	9
Wind (kph):	nil
Cloud cover (%):	0
Comment:	Good soil conditions for nematicide application and incorporation.

3.1.2. Assessment Methods

The following assessments were carried out on the trial:

3.1.2.1. Site selection

Fields with the required PCN infestation levels were selected on the basis of normal commercial PCN sampling at one hectare sampling units. Suitable areas within fields were re-sampled on a 20 metre square grid to confirm required PCN level and uniformity of the infestation.

3.1.2.2. At application

Soil and climatic data was collected at application.
Composite soil samples were taken from each treatment block for assessment of initial PCN level (Pi) and species composition. Each soil sample comprised sixty soil cores taken with a 1cm diameter auger from 0-20cm depth.

3.1.2.3. Crop vigour

Assessment of haulm volume was carried out to assess the vigour of plants on 16.06.2010 (65 days after planting) and 12.07.2010 (91 days after planting). Crop vigour/haulm volume was assessed as % crop ground cover.

3.1.2.4. Potato yield and grade

Each three metre variety plot was harvested and graded by hand. The following tuber size grades were recorded:

<45mm; 45-60mm; >60mm; Total yield

3.1.2.5. Potato Cyst Nematode (PCN) – post harvest.

Sixty soil cores (0-20cms) were taken from each plot at lifting, using a 1cm diameter auger. The soil samples were analysed for PCN level (e+l/g soil) at GrowScience (Holbeach).

3.2. 2011 Trial

Co-operator: Proctor Bros. (Gosberton) Ltd.
Site: Gosberton, Spalding
Grid reference: TF 272276
Soil type: Silt loam
Previous crop (2010): Winter wheat
Crop & Cultivar: Potato – 14 varieties were planted at 20cm spacing. Tightly graded seed (35-45mm) of a similar physiological age was planted.
Planting Date: 14.04.2011
Field Preparation: Mouldboard plough (winter)
Power harrow
Basalier bedtiller (to incorporate nematicide)
Planter – to form ridges only.
Hand plant.

Plot Maintenance Late blight, weed and insect control consistent with good local practice.
Previous treatments: Nil
Plot size: 1 row X 3m
Design: RCB – first block not randomised. Three replicates.

TABLE 2 - TREATMENT LIST

	Treatment	Rate / ha	Timing
1	Maris Peer		
1a	Maris Peer + Vydate	55kg/ha	Pre-planting
2	Cara		
2a	Cara + Vydate	55kg/ha	Pre-planting
3	Vales Everest		
3a	Vales Everest + Vydate	55kg/ha	Pre-planting
4	Innovator		
4a	Innovator + Vydate	55kg/ha	Pre-planting
5	Desiree		
5a	Desiree + Vydate	55kg/ha	Pre-planting
6	Chicago		
6a	Chicago + Vydate	55kg/ha	Pre-planting
7	Sierra Gold		
7a	Sierra Gold + Vydate	55kg/ha	Pre-planting
8	Jelly		
8a	Jelly + Vydate	55kg/ha	Pre-planting
9	Saxon		
9a	Saxon + Vydate	55kg/ha	Pre-planting
10	Sapphire		
10a	Sapphire + Vydate	55kg/ha	Pre-planting
11	Markies		
11a	Markies + Vydate	55kg/ha	Pre-planting
12	Melody		
12a	Melody + Vydate	55kg/ha	Pre-planting
13	Cabaret		
13a	Cabaret + Vydate	55kg/ha	Pre-planting
14	Harmony		
14a	Harmony + Vydate	55kg/ha	Pre-planting

TABLE 2A - PRODUCT LIST

Product	Active Ingredient	g/l or kg	Formulation	Batch Number
Vydate	oxamyl	10% w/w	GR	JUN10CE130

3.2.1. Application Details

Nematicide granules were broadcast evenly over the ploughed soil surface using a Maxicast nematicide granule applicator. Granules were then immediately incorporated into the top 15cm soil using a Basalier bedtiller, prior to planting.

T1

Date:	10.04.2011
Crop Stage:	Pre-planting – four days prior to hand planting.
Crop Cover:	n/a
Leaf Moisture:	n/a
Soil Moisture (Surface):	Damp
Soil Moisture (Sub-surface):	Moist
Soil Condition:	Loose
Soil Tilth:	Small clods

Weather at application

Air temperature (Deg. C):	17
Soil temperature (Deg. C):	11
Wind (kph):	3
Cloud cover (%):	0
Comment:	Good, dry soil conditions for nematicide application and incorporation.

3.2.2. Assessment methods

The following assessments were carried out on the trial:

3.2.2.1. Site selection

Fields with the required PCN infestation levels were selected on the basis of normal commercial PCN sampling at one hectare sampling units. Suitable areas within fields were re-sampled on a 20 metre square grid to confirm required PCN level and uniformity of the infestation.

3.2.2.2. At application

Soil and climatic data was collected at application. Composite soil samples were taken from each treatment block for assessment of initial PCN level (Pi) and species composition. Each soil sample comprised sixty soil cores taken with a 1cm diameter auger from 0-20cm depth.

3.2.2.3. Crop vigour

Assessment of haulm volume was carried out to assess the vigour of plants on 24.05.2011 (65 days after planting) and 20.06.2011 (91 days after planting). Crop vigour/haulm volume was assessed as % crop ground cover.

3.2.2.4. Potato yield and grade

Each three metre variety plot was harvested and graded by hand. The following tuber size grades were recorded:
<45mm; 45-60mm; >60mm; Total yield

3.2.2.5. Potato Cyst Nematode (PCN) – post harvest.

Sixty soil cores (0-20cms) were taken from each plot at lifting, using a 1cm diameter auger. The soil samples were analysed for PCN level (e+l/g soil) at Richard Austin Agriculture Limited (Boston).

3.3. 2012 Trial

Co-operator:	Clifford Pye Ltd,
Site:	Cawston, Norwich
Grid reference:	TG 145256
Soil type:	Sandy loam
Previous crop (2011):	Winter wheat
Crop & Cultivar:	Potato – 14 varieties were planted at 20cm spacing. Tightly graded seed (35-45mm) of a similar physiological age was planted.
Planting Date:	11.05.2012
Field Preparation:	Mouldboard plough (spring) Overall broadcast nematicide. Ridged De-stoned Planter – to form ridges only. Hand plant.
Plot Maintenance	Late blight, weed and insect control consistent with good local practice.
Previous treatments:	Nil
Plot size:	1 row X 3m
Design:	RCB – first block not randomised. Three replicates.

TABLE 3 TREATMENT LIST

	Treatment	Rate / ha	Timing
1	Maris Peer		
2	Maris Peer + Vydate	55kg/ha	Pre-planting
3	Cara		
4	Cara + Vydate	55kg/ha	Pre-planting
5	Vales Everest		
6	Vales Everest + Vydate	55kg/ha	Pre-planting
7	Innovator		
8	Innovator + Vydate	55kg/ha	Pre-planting
9	Desiree		
10	Desiree + Vydate	55kg/ha	Pre-planting
11	Chicago		
12	Chicago + Vydate	55kg/ha	Pre-planting
13	Ramos*		
14	Ramos* + Vydate	55kg/ha	Pre-planting
15	Jelly		
16	Jelly + Vydate	55kg/ha	Pre-planting
17	Saxon		
18	Saxon + Vydate	55kg/ha	Pre-planting
19	Sapphire		
20	Sapphire + Vydate	55kg/ha	Pre-planting
21	Markies		
22	Markies + Vydate	55kg/ha	Pre-planting
23	Melody		
24	Melody + Vydate	55kg/ha	Pre-planting
25	Cabaret		
26	Cabaret + Vydate	55kg/ha	Pre-planting
27	Harmony		
28	Harmony + Vydate	55kg/ha	Pre-planting

* Ramos was substituted for Sierra Gold in 2012. This was due to the unavailability of the variety Sierra Gold

TABLE 3A PRODUCT LIST

Product	Active Ingredient	g/l or kg	Formulation	Batch Number
Vydate	oxamyl	10% w/w	GR	JUN10CE130

3.3.1. Application Details

Nematicide granules were broadcast evenly over the ploughed soil surface using a Horstine TMA-4 granule applicator. Granules were then immediately incorporated into the soil by ridging, de-stoning and planting.

T1

Date:	27.04.2012
Crop Stage:	pre-planting – fourteen days prior to hand planting (heavy rainfall caused a delay between nematicide application and planting).
Crop Cover:	n/a
Leaf Moisture:	n/a
Soil Moisture (Surface):	moist
Soil Moisture (Sub-surface):	wet
Soil Condition:	loose
Soil Tilth:	fine

Weather at application

Air temperature (Deg. C):	11
Soil temperature (Deg. C):	9
Wind (kph):	7 - west
Cloud cover (%):	100
Comment:	Good, dry soil conditions for nematicide application and incorporation.

3.3.2. Assessment Methods

The following assessments were carried out on the trial:

3.3.2.1. Site selection

Fields with the required PCN infestation levels were selected on the basis of normal commercial PCN sampling at one hectare sampling units. Suitable areas within fields were re-sampled on a 20 metre square grid to confirm required PCN level and uniformity of the infestation.

3.3.2.2. At application

Soil and climatic data was collected at application. Composite soil samples were taken from each treatment block for assessment of initial PCN level (Pi) and species composition. Each soil sample comprised sixty soil cores taken with a 1cm diameter auger from 0-20cm depth.

3.3.2.3. Crop vigour

Assessment of haulm volume was carried out to assess the vigour of plants on 17.06.2012 (37 days after planting) and 13.07.2012 (63 days after planting). Crop vigour/haulm volume was assessed as % crop ground cover.

3.3.2.4. Potato yield and grade

Each three metre variety plot was harvested and graded by hand. The following tuber size grades were recorded:

<45mm
45-60mm
>60mm
Total yield

3.3.2.5. Potato Cyst Nematode (PCN) – post harvest.

Sixty soil cores (0-20cms) were taken from each plot at lifting, using a 1cm diameter auger. The soil samples were analysed for PCN level (e+l/g soil) at Richard Austin Agriculture Limited (Boston).

4. RESULTS

4.1. 2010 Trial

TABLE 4 - PCN LEVELS IN THE TRIAL AREA (PI) – SAMPLED 08.04.2010

Sample area	Total cysts/100g soil	eggs/g soil
Block 1	57	14
Block 2	61	16
Block 3	63	17

Initial PCN levels showed an even infestation over the trial area, allowing comparison between nematicide-treated plots and untreated plots. The high numbers of cysts present in all samples, indicated a long-standing infestation.

TABLE 4A - SPECIATION OF PCN IN TRIAL AREA

Characteristic band patterns of:	
***Globodera pallida* (%)**	***Globodera rostochiensis* (%)**
100	0

PCN speciation was determined using DNA assay techniques (work conducted by NIAB Labtest, Cambridge). The trial area contained a single species PCN population of *Globodera pallida*.

4.1.1. Crop vigour (haulm volume / % ground cover).

An indirect method of assessing varietal tolerance is to compare the vigour of a variety grown with and without a nematicide. Small differences in vigour between the nematicide treated and untreated plots would indicate good tolerance to PCN damage. Conversely, large differences in crop vigour indicate lower levels of tolerance to PCN. Crop vigour assessments are shown in Table 5 and Figures 1-2 below.

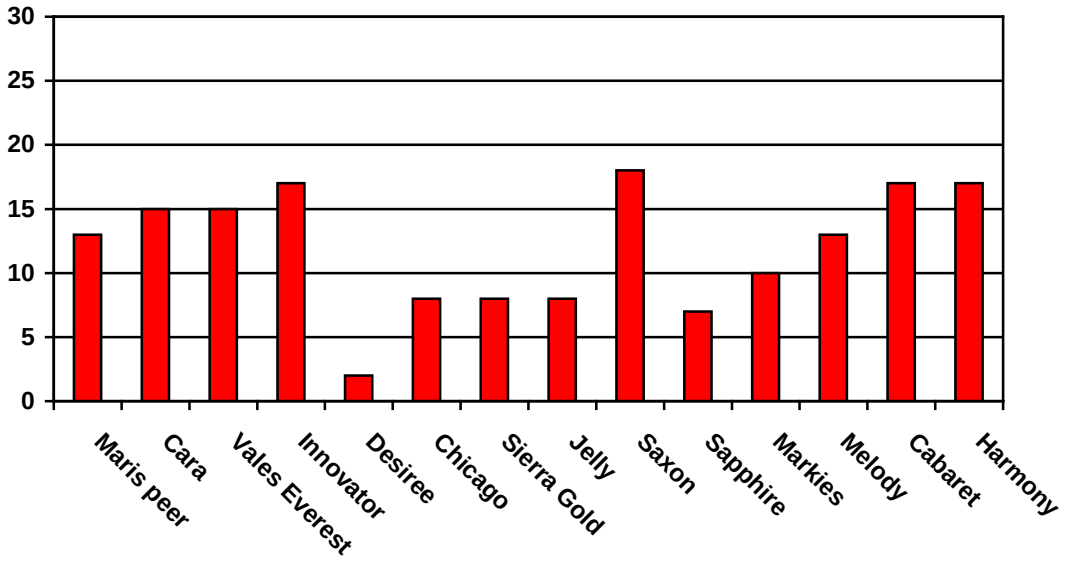

FIGURE 1 – EFFECT OF NEMATICIDE ON INCREASE IN % CROP GROUND COVER 16.06.2010

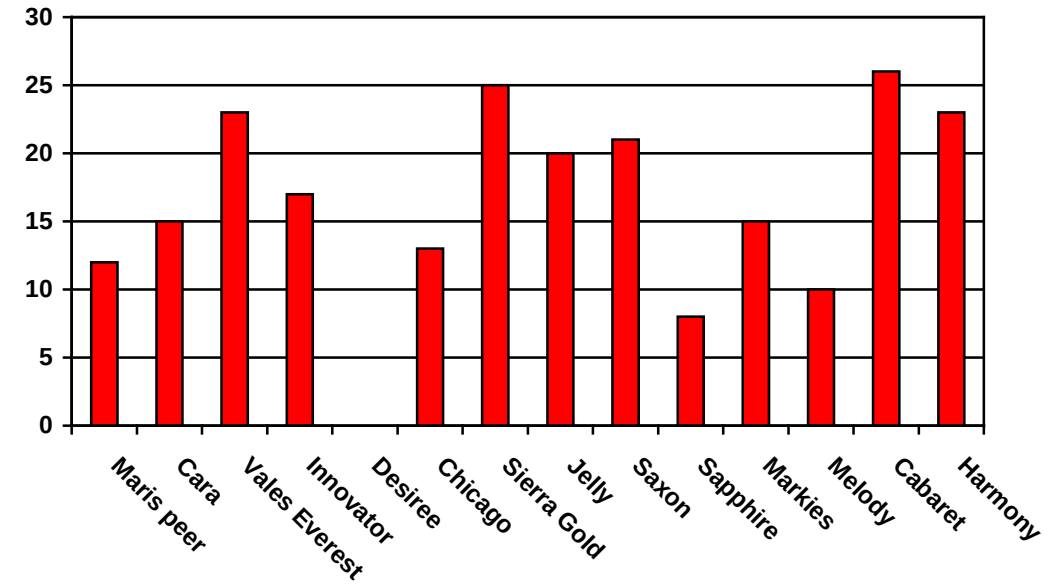

FIGURE 2 – EFFECT OF NEMATICIDE ON INCREASE IN % CROP GROUND COVER 12.07.2010

TABLE 5 – CROP VIGOUR (% GROUND COVER) ASSESSED 16.06.2010 AND 12.07.2010.

Part Rated		Haulm		Haulm	
Rating Date		16/Jun/2010		12/Jul/2010	
Rating Data Type		Groundcover		Groundcover	
Rating Unit		%		%	
Treatment	Treatment				
1	Maris Peer	37	j-m	55	g-j
2	Maris Peer + Vydate (55kg)	50	d-i	67	d-g
3	Cara	52	d-i	77	cde
4	Cara + Vydate (55kg)	67	ab	92	ab
5	Vales Everest	50	d-i	68	d-g
6	Vales Everest + Vydate (55kg)	65	abc	91	ab
7	Innovator	35	klm	48	hij
8	Innovator + Vydate (55kg)	52	d-i	65	efg
9	Desiree	53	c-h	72	def
10	Desiree + Vydate (55kg)	55	b-g	72	def
11	Chicago	42	h-l	60	f-i
12	Chicago + Vydate (55kg)	50	d-i	73	def
13	Sierra Gold	47	f-k	48	hij
14	Sierra Gold + Vydate (55kg)	55	b-g	73	def
15	Jelly	37	j-m	68	d-g
16	Jelly + Vydate (55kg)	45	f-k	88	abc
17	Saxon	30	lm	47	ij
18	Saxon + Vydate (55kg)	48	e-j	68	d-g
19	Sapphire	43	g-k	72	def
20	Sapphire + Vydate (55kg)	50	d-i	80	bcd
21	Markies	62	a-d	80	bcd
22	Markies + Vydate (55kg)	72	a	95	a
23	Melody	47	f-k	68	d-g
24	Melody + Vydate (55kg)	60	a-e	78	b-e
25	Cabaret	40	i-m	62	fgh
26	Cabaret + Vydate (55kg)	57	b-f	88	abc
27	Harmony	28	m	45	j
28	Harmony + Vydate (55kg)	45	f-k	68	d-g
LSD (P=.05)			11.8		14.0
Standard Deviation			7.3		8.6
CV			14.81		12.2
Replicate F			0.074		3.066
Replicate Prob(F)			0.9292		0.0548
Treatment F			6.396		7.690
Treatment Prob(F)			0.0001		0.0001

Means followed by same letter do not significantly differ (P=.05, LSD)

Use of nematicide increased crop vigour in all varieties except Desiree, many of these vigour increases were significant (P=0.05). Cabaret, Harmony, Sierra Gold, Vales Everest and Saxon showed the greatest vigour increases due to nematicide application, indicating that these varieties may be among the least tolerant to PCN. However, % vigour increase was not always well correlated with % total yield increase.

4.1.2. Potato yield and grade.

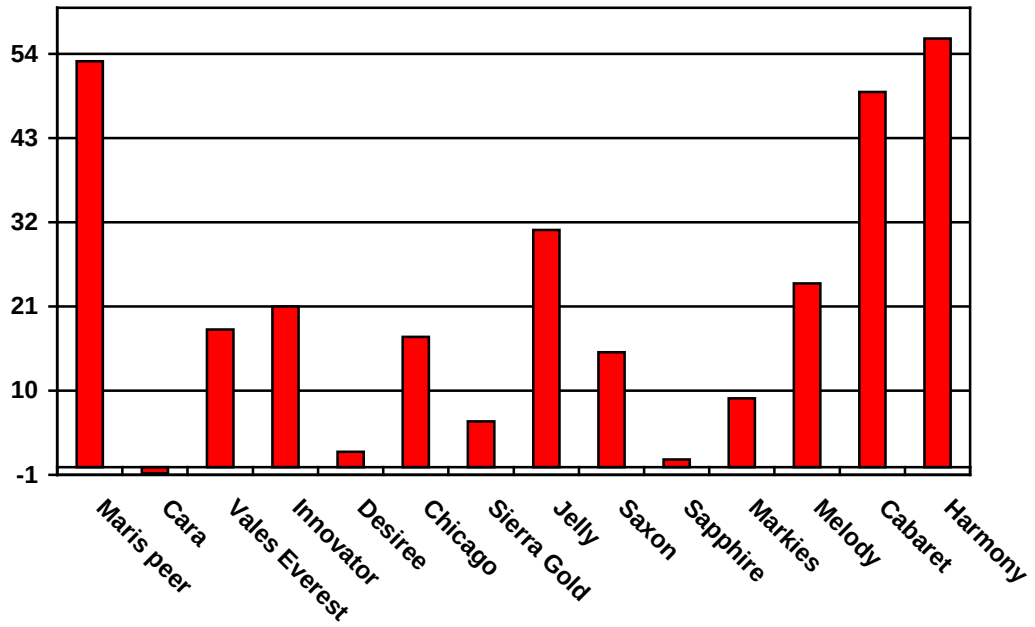

FIGURE 3 – EFFECT OF NEMATICIDE ON % INCREASE IN TOTAL YIELD

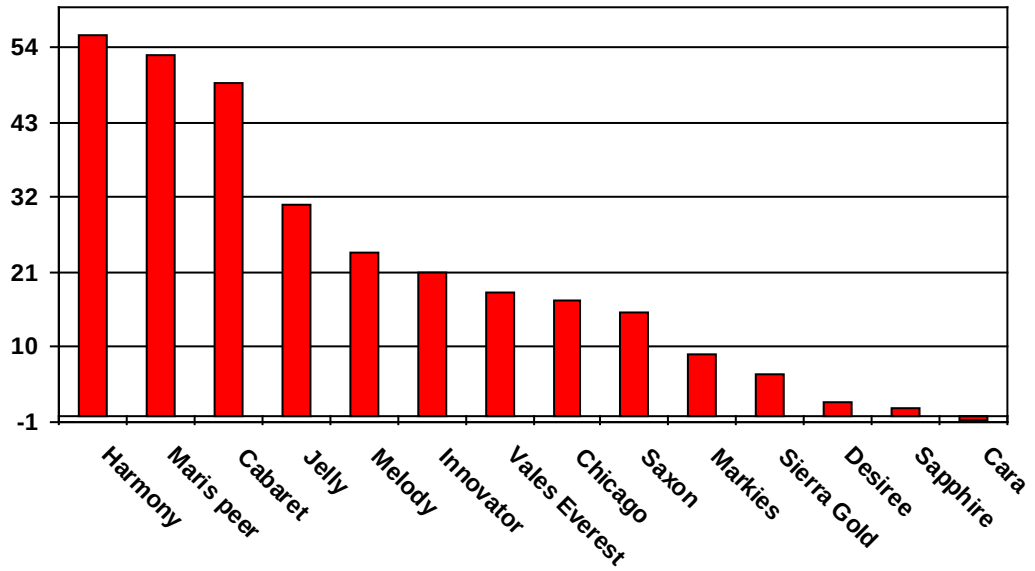

FIGURE 4 - EFFECT OF NEMATICIDE ON % INCREASE IN TOTAL YIELD (RANKED DATA)

TABLE 6 – EFFECT OF NEMATICIDE ON YIELD AND GRADE OF POTATOES (T/HA).

Part Rated		Tuber		Tuber		Tuber		Tuber	
Rating Date		21/Sep/2010		21/Sep/2010		21/Sep/2010		21/Sep/2010	
Rating Data Type		<45mm		45-60mm		>60mm		Total Yield	
Rating Unit		t/ha		t/ha		t/ha		t/ha	
Trt	**Treatment**								
1	Maris Peer	6.8	ab	14.7	ghi	3.6	l	25.1	m
2	Maris Peer + Vydate (55kg)	7.4	a	20.8	a-e	10.2	kl	38.4	jkl
3	Cara	4.4	c-f	15.5	f-i	48.3	bc	68.2	a-d
4	Cara + Vydate (55kg)	2.9	f-j	17.0	d-h	47.7	bc	67.6	bcd
5	Vales Everest	2.9	f-j	12.0	ijk	51.8	b	66.7	b-e
6	Vales Everest + Vydate (55kg)	2.0	i-m	12.2	ij	64.7	a	79.0	a
7	Innovator	2.1	i-m	14.9	ghi	12.9	i-l	29.9	lm
8	Innovator + Vydate (55kg)	4.8	cd	21.3	abc	12.1	jkl	38.2	jkl
9	Desiree	3.7	d-h	20.6	a-e	28.6	fgh	52.9	f-i
10	Desiree + Vydate (55kg)	4.4	c-f	16.7	e-h	32.9	d-g	54.0	f-i
11	Chicago	2.2	h-l	18.8	b-g	22.8	g-j	43.9	ijk
12	Chicago + Vydate (55kg)	3.5	d-i	21.2	a-d	26.6	gh	51.3	f-i
13	Sierra Gold	2.0	i-m	8.1	jkl	24.9	gh	35.0	klm
14	Sierra Gold + Vydate (55kg)	1.7	j-m	7.2	l	28.2	fgh	37.0	jkl
15	Jelly	4.9	cd	23.9	a	25.7	gh	54.5	f-i
16	Jelly + Vydate (55kg)	4.6	cde	22.2	ab	44.4	bcd	71.2	abc
17	Saxon	2.7	h-l	12.5	i	18.7	h-k	33.9	klm
18	Saxon + Vydate (55kg)	1.8	j-m	12.5	i	24.7	ghi	38.9	jkl
19	Sapphire	0.7	m	5.2	l	69.8	a	75.6	ab
20	Sapphire + Vydate (55kg)	1.3	klm	4.0	l	71.0	a	76.4	ab
21	Markies	3.1	e-j	19.9	a-e	30.3	e-h	53.3	f-i
22	Markies + Vydate (55kg)	4.3	d-g	21.0	a-d	33.0	d-g	58.2	d-g
23	Melody	4.8	cd	19.2	b-f	26.4	gh	50.4	ghi
24	Melody + Vydate (55kg)	4.5	cde	17.2	c-h	40.7	b-e	62.4	c-f
25	Cabaret	7.4	a	18.6	b-g	5.0	l	31.1	lm
26	Cabaret + Vydate (55kg)	5.8	bc	21.2	a-d	19.4	h-k	46.4	hij
27	Harmony	1.2	lm	7.9	kl	26.5	gh	35.6	j-m
28	Harmony + Vydate (55kg)	2.8	g-k	14.1	hi	38.6	c-f	55.5	e-h
LSD (P=.05)		1.53		4.20		11.97		11.33	
Standard Deviation		0.94		2.57		7.33		6.94	
CV		25.96		16.35		23.09		13.58	
Replicate F		0.614		4.319		0.632		2.244	
Replicate Prob(F)		0.5448		0.0182		0.5355		0.1159	
Treatment F		11.468		13.828		17.876		15.070	
Treatment Prob(F)		0.0001		0.0001		0.0001		0.0001	

Means followed by same letter do not significantly differ (P=.05, LSD)

Nematicide application resulted in a yield increase in all varieties except Cara. Many of the yield increases were significant (P=0.05). However, the size of yield increase varied greatly with variety, indicating a wide range of PCN tolerance levels within the varieties tested.

Maris Peer, Harmony and Cabaret showed the largest yield increases due to nematicide use, indicating that these varieties have low tolerance to PCN. Conversely, Cara, Sapphire and Desiree exhibited a higher level of tolerance to PCN.

4.1.3. PCN population dynamics.

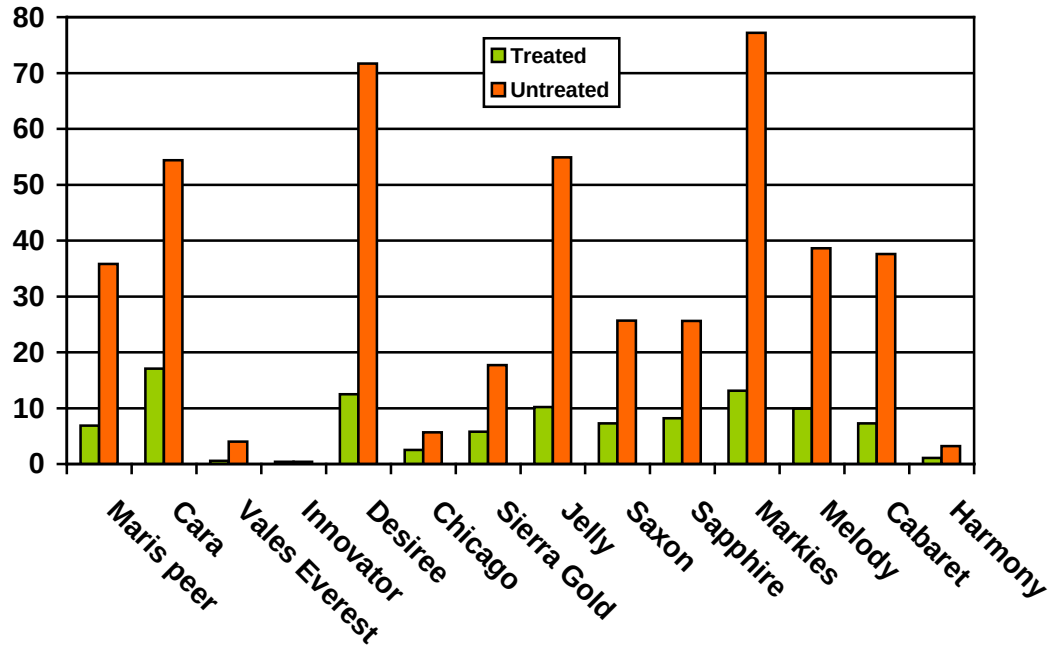

FIGURE 5 – EFFECT OF VARIETY AND NEMATICIDE ON PCN POPULATION DYNAMICS (PF:PI)

Use of a nematicide has reduced the PCN population increase (Pf:Pi) for all varieties tested. Several of the reductions are significant (P=0.05). Variety greatly influenced the PCN population increase (Pf:Pi), both in the presence and especially in the absence, of a nematicide.

Nematicide use generally restricted Pf:Pi values to around 10 for most varieties. Markies, Desiree and Cara showed the highest rate of PCN multiplication, especially when grown without a nematicide. The more tolerant varieties generally resulted in the higher PCN multiplication rates. Vales Everest treated with a nematicide reduced the level of *G. pallida* in the soil. Innovator, both treated and untreated, also reduced the level of *G. pallida* in the soil.

TABLE 7 – THE EFFECT OF VARIETY AND NEMATICIDE ON PCN POPULATION DYNAMICS (PF:PI).

Pest Name			***Globodera pallida***
Rating Date			**21/Sep/2010**
Rating Data Type			**Pf:Pi ratio**
Trt No.	**Treatment Name**		**12**
1	Maris Peer	35.8	c
2	Maris Peer + Vydate (55kg)	6.9	ef
3	Cara	54.4	b
4	Cara + Vydate (55kg)	17.1	de
5	Vales Everest	4.0	ef
6	Vales Everest + Vydate (55kg)	0.6	f
7	Innovator	0.4	f
8	Innovator + Vydate (55kg)	0.4	f
9	Desiree	71.7	a
10	Desiree + Vydate (55kg)	12.5	def
11	Chicago	5.7	ef
12	Chicago + Vydate (55kg)	2.5	f
13	Sierra Gold	17.7	de
14	Sierra Gold + Vydate (55kg)	5.8	ef
15	Jelly	54.9	b
16	Jelly + Vydate (55kg)	10.2	ef
17	Saxon	25.7	cd
18	Saxon + Vydate (55kg)	7.3	ef
19	Sapphire	25.6	cd
20	Sapphire + Vydate (55kg)	8.2	ef
21	Markies	77.2	a
22	Markies + Vydate (55kg)	13.1	def
23	Melody	38.6	c
24	Melody + Vydate (55kg)	9.9	ef
25	Cabaret	37.6	c
26	Cabaret + Vydate (55kg)	7.3	ef
27	Harmony	3.2	f
28	Harmony + Vydate (55kg)	1.1	f
LSD (P=.05)			13.85
Standard Deviation			8.48
CV			42.75
Replicate F			4.986
Replicate Prob(F)			0.0103
Treatment F			20.124
Treatment Prob(F)			0.0001

Means followed by same letter do not significantly differ (P=.05, LSD)

4.2. 2011 Trial

TABLE 8 - PCN LEVELS IN THE TRIAL AREA (PI) – SAMPLED 10.04.2011

Sample area	**Total cysts/100g soil**	**eggs/g soil**
Block 1	57	9
Block 2	57	12
Block 3	75	14

Initial PCN levels showed an even infestation over the trial area, allowing comparison between nematicide-treated plots and untreated plots. The high numbers of cysts present in all samples, indicated a long-standing infestation.

TABLE 8A - SPECIATION OF PCN IN TRIAL AREA

Characteristic band patterns of:	
***Globodera pallida* (%)**	***Globodera rostochiensis* (%)**
100	0

PCN speciation was determined using DNA assay techniques (work conducted by NIAB Labtest, Cambridge). The trial area contained a single species PCN population of *Globodera pallida*.

4.2.1. Crop vigour (haulm volume / % ground cover).

Crop vigour assessments are shown in Table 9 and Figures 6 and 7 below.

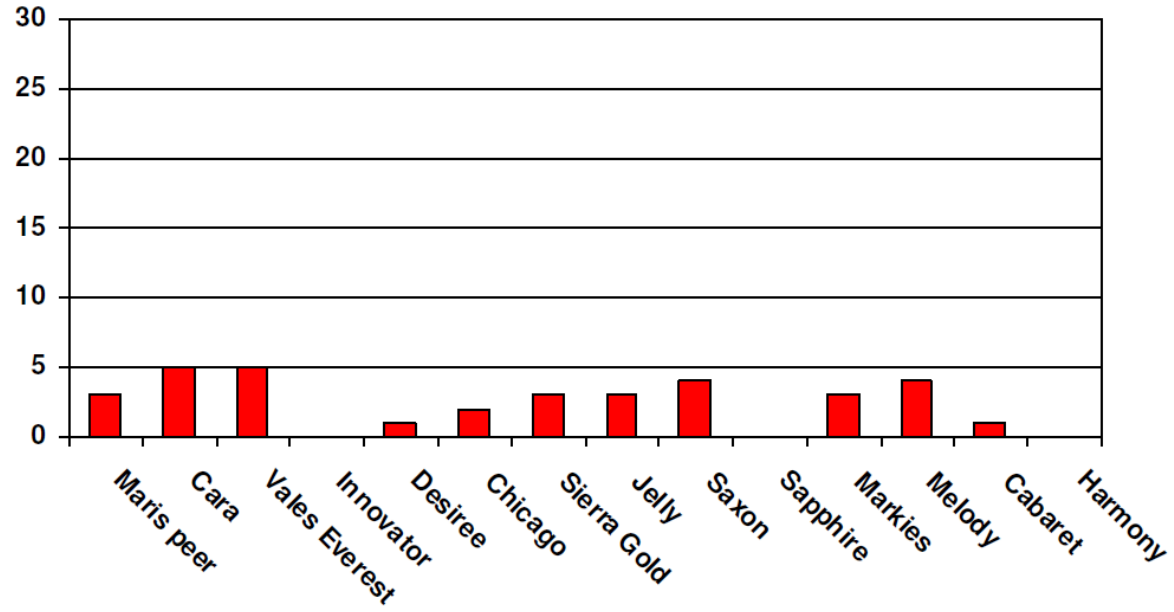

FIGURE 6 – EFFECT OF NEMATICIDE ON INCREASE IN % CROP GROUND COVER 24.05.2011

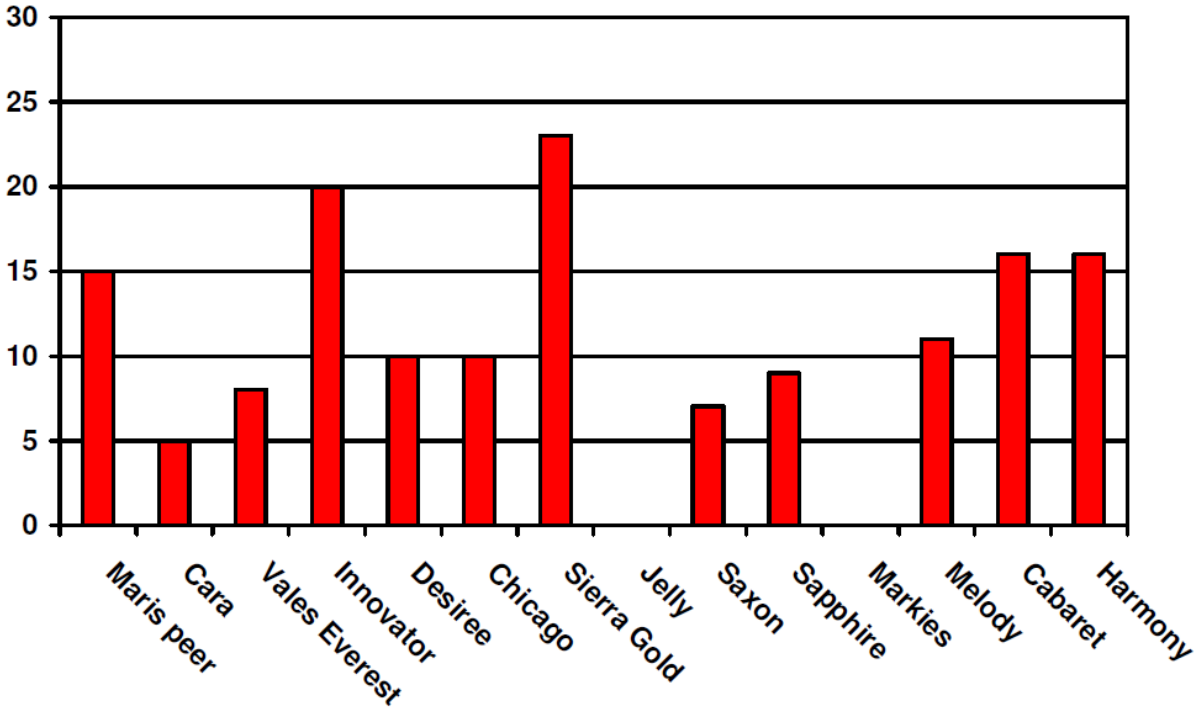

FIGURE 7 – EFFECT OF NEMATICIDE ON INCREASE IN % CROP GROUND COVER 20.06.2011

TABLE 9 – CROP VIGOUR (% GROUND COVER) ASSESSED 24.05.2011 AND 20.06.2011.

Part Rated		Haulm	Haulm
Rating Date		24/May/2011	20/Jun/2011
Rating Data Type		Groundcover	Groundcover
Rating Unit		%	%
Treatment	Treatment		
1	Maris Peer	4k	55hi
2	Maris Peer + Vydate (55kg)	7h-k	70d-g
3	Cara	8f-i	88abc
4	Cara + Vydate (55kg)	13bc	93ab
5	Vales Everest	11cde	90abc
6	Vales Everest + Vydate (55kg)	16a	98a
7	Innovator	5ijk	45ij
8	Innovator + Vydate (55kg)	5ijk	65fgh
9	Desiree	7h-k	68e-h
10	Desiree + Vydate (55kg)	8f-i	78c-f
11	Chicago	5ijk	67e-h
12	Chicago + Vydate (55kg)	7g-j	77c-f
13	Sierra Gold	7h-k	57ghi
14	Sierra Gold + Vydate (55kg)	10d-g	80cde
15	Jelly	5jk	73def
16	Jelly + Vydate (55kg)	8f-i	73def
17	Saxon	8e-i	73def
18	Saxon + Vydate (55kg)	12bcd	80cde
19	Sapphire	5jk	58gh
20	Sapphire + Vydate (55kg)	5jk	67e-h
21	Markies	11c-f	94ab
22	Markies + Vydate (55kg)	14ab	94ab
23	Melody	5ijk	67e-h
24	Melody + Vydate (55kg)	9e-h	78c-f
25	Cabaret	7g-k	67e-h
26	Cabaret + Vydate (55kg)	8ghi	83bcd
27	Harmony	1l	42j
28	Harmony + Vydate (55kg)	1l	58gh
LSD (P=.05)		2.5	11.5
Standard Deviation		1.5	7.0
CV		20.3	9.66
Replicate F		0.931	0.065
Replicate Prob(F)		0.4002	0.9370
Treatment F		15.553	13.021
Treatment Prob(F)		0.0001	0.0001

Means followed by same letter do not significantly differ (P=.05, LSD)

Use of nematicide increased crop vigour (20.06.2011) in all varieties except Markies and Jelly, many of these vigour increases were significant (P=0.05). Cabaret, Harmony, Sierra Gold and Maris Peer showed the greatest vigour increases due to nematicide application, indicating that these varieties may be among the least tolerant to PCN. This order of vigour increase due to nematicide application is very similar to data for 2010. However, % vigour increase is not always well correlated with % total yield increase.

4.2.2. Potato yield and grade.

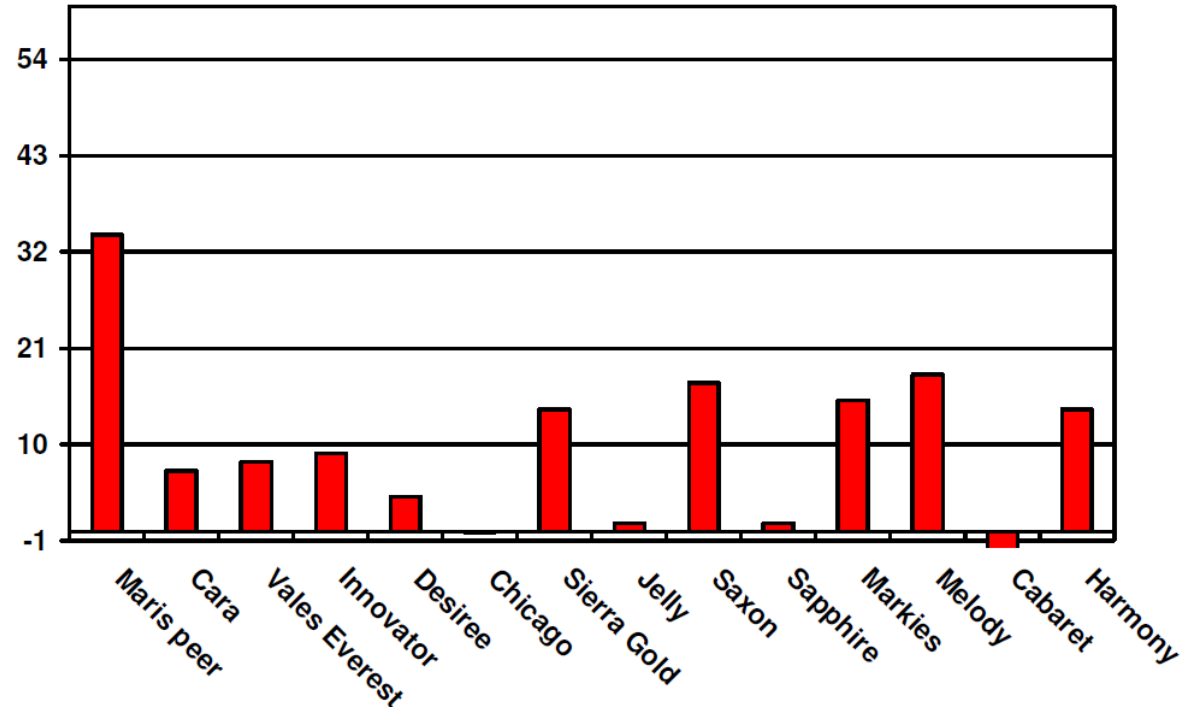

FIGURE 8 – EFFECT OF NEMATICIDE ON % INCREASE IN TOTAL YIELD.

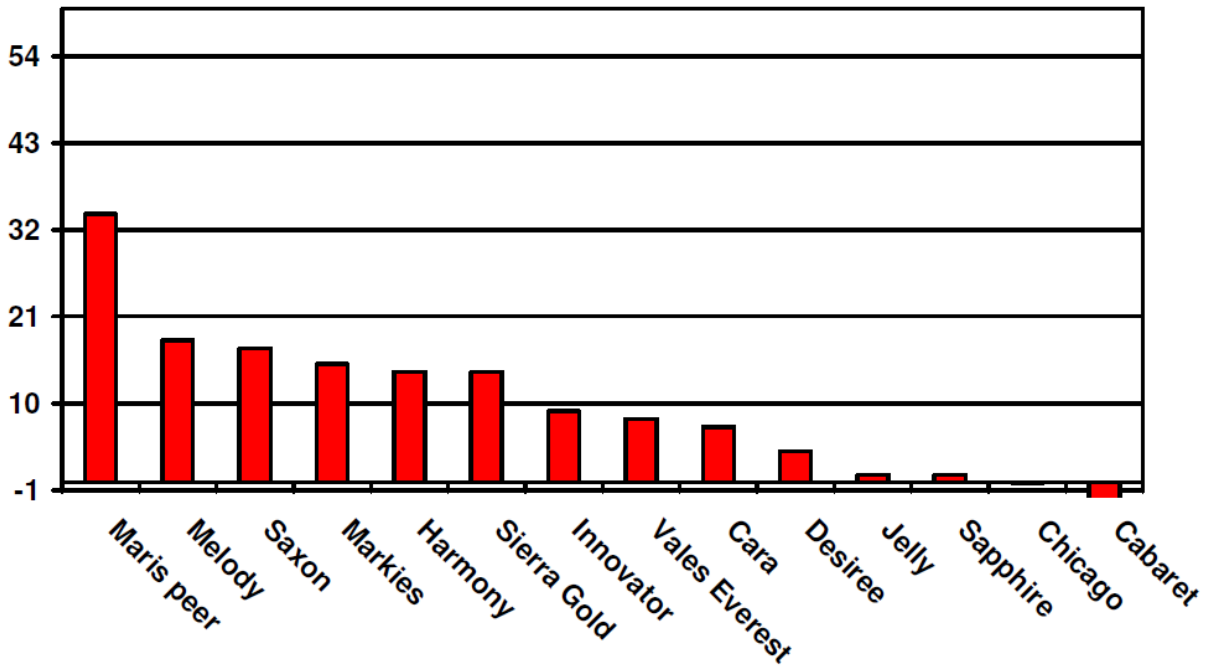

FIGURE 9 - EFFECT OF NEMATICIDE ON % INCREASE IN TOTAL YIELD (RANKED DATA).

TABLE 10 – EFFECT OF NEMATICIDE ON YIELD AND GRADE OF POTATOES (T/HA).

Part Rated		Tuber	Tuber	Tuber	Tuber
Rating Date		27.09.2011	27.09.2011	27.09.2011	27.09.2011
Rating Data Type		<45mm	45-60mm	>60mm	Total Yield
Rating Unit		t/ha	t/ha	t/ha	t/ha
Trt	Treatment				
1	Maris peer	13.3a	16.4d-g	1.3j	31.1m
2	Maris peer + Vydate (55kg)	12.8a	24.2bc	4.7j	41.7kl
3	Cara	2.4d-g	10.8ghi	60.1ab	73.2ab
4	Cara + Vydate (55kg)	1.9efg	12.5f-i	63.8a	78.2a
5	Vales Everest	3.6c-g	17.6def	49.2cde	70.4ab
6	Vales Everest + Vydate (55kg)	3.6c-g	17.6def	54.8a-d	76.0ab
7	Innovator	1.6fg	7.3i	28.0gh	36.8lm
8	Innovator + Vydate (55kg)	3.0d-g	14.6e-h	21.4hi	39.0lm
9	Desiree	4.0cde	17.6def	37.6fg	59.2efg
10	Desiree + Vydate (55kg)	2.9d-g	19.7cde	38.9ef	61.6def
11	Chicago	4.2cd	33.8a	19.4hi -	57.3f
12	Chicago + Vydate (55kg)	3.8c-f	33.8a	19.3hi	56.9f-i
13	Sierra Gold	1.5g	7.7i	40.2ef	49.4h-k
14	Sierra Gold + Vydate (55kg)	1.6fg	8.9hi	46.1def	56.5f-i
15	Jelly	1.9efg	7.6i	64.0a	73.6ab
16	Jelly + Vydate (55kg)	1.5g	8.6hi	64.5a	74.6ab
17	Saxon	2.8d-g	13.1f-i	36.2fg	52.2g-j
18	Saxon + Vydate (55kg)	2.1d-g	16.4d-g	44.5def	63.0c-f
19	Sapphire	1.6fg	8.7hi	57.3abc	67.6b-e
20	Sapphire + Vydate (55kg)	1.9efg	9.1hi	57.5abc	68.5bcd
21	Markies	2.6d-g	13.0f-i	53.0bcd	68.6bcd
22	Markies + Vydate (55kg)	2.1d-g	16.5d-g	60.2ab	78.9a
23	Melody	6.4b	22.2bcd	20.6hi	49.2h-k
24	Melody + Vydate (55kg)	6.5b	26.2b	25.2hi	58.0fgh
25	Cabaret	6.8b	25.0bc	17.0i	48.8ijk
26	Cabaret + Vydate (55kg)	5.7bc	25.2bc	16.5i	47.4jk
27	Harmony	3.8c-f	10.2hi	37.8fg	51.8g-j
28	Harmony + Vydate (55kg)	3.8c-f	16.5d-g	38.6f	58.9fg
LSD (P=.05)		1.84	5.25	9.29	7.75
Standard Deviation		1.13	3.22	5.69	4.75
CV		28.79	19.53	14.77	8.06
Replicate F		0.181	0.412	2.045	1.670
Replicate Prob(F)		0.8346	0.6642	0.1393	0.1978
Treatment F		21.572	16.531	32.371	22.854
Treatment Prob(F)		0.0001	0.0001	0.0001	0.0001

Means followed by same letter do not significantly differ (P=.05, LSD)

Nematicide application resulted in a yield increase in all varieties except Chicago and Cabaret, few of these yield increases were significant (P=0.05). The use of nematicides did not raise yields as much as in previous trials. Very dry soil conditions during the early season probably limited the efficacy of the nematicide.

The “standard” varieties for PCN tolerance, Maris Peer and Cara, behaved as expected but the yield responses of other varieties, sometimes differed from previous trials.

4.2.3. PCN population dynamics.

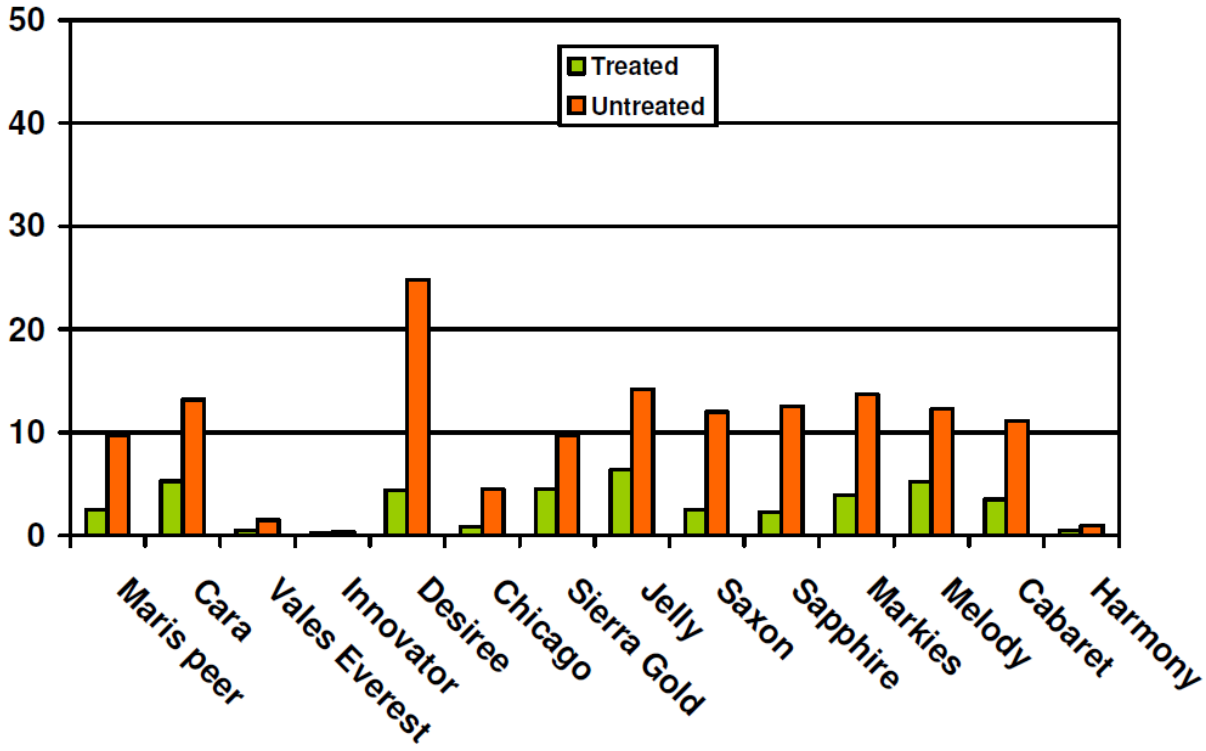

FIGURE 10 – EFFECT OF VARIETY AND NEMATICIDE ON PCN POPULATION DYNAMICS (PF:PI).

Use of a nematicide has reduced the PCN population increase (Pf:Pi) for all varieties tested. Some of the reductions are significant (P=0.05). Nematicide use generally restricted Pf:Pi values to around 5 for most varieties. Markies, Jelly, Desiree and Cara showed the highest rate of PCN multiplication, especially when grown without a nematicide. The more tolerant varieties generally resulted in the higher PCN multiplication rates. Vales Everest and Harmony, treated with a nematicide, reduced the level of *G. pallida* in the soil. Innovator, both treated and untreated, also reduced the level of *G. pallida* in the soil.

TABLE 11 – THE EFFECT OF VARIETY AND NEMATICIDE ON PCN POPULATION DYNAMICS (PF:PI).

Part rated Rating Data Type		Eggs/g soil Pf:Pi ratio
Treatment No.	**Treatment Name**	**12**
1	Maris Peer	9.7b-g
2	Maris Peer + Vydate (55kg)	2.5fg
3	Cara	13.2bcd
4	Cara + Vydate (55kg)	5.3b-g
5	Vales Everest	1.5g
6	Vales Everest + Vydate (55kg)	0.5g
7	Innovator	0.4g
8	Innovator + Vydate (55kg)	0.3g
9	Desiree	24.8a
10	Desiree + Vydate (55kg)	4.4c-g
11	Chicago	4.5c-g
12	Chicago + Vydate (55kg)	0.9g
13	Sierra Gold	9.7b-g
14	Sierra Gold + Vydate (55kg)	4.5c-g
15	Jelly	14.2b
16	Jelly + Vydate (55kg)	6.4b-g
17	Saxon	12.0b-
18	Saxon + Vydate (55kg)	2.5fg
19	Sapphire	12.5b-e
20	Sapphire + Vydate (55kg)	2.3fg
21	Markies	13.7bc
22	Markies + Vydate (55kg)	3.9d-g
23	Melody	12.3b-e
24	Melody + Vydate (55kg)	5.2b-g
25	Cabaret	11.1b-f
26	Cabaret + Vydate (55kg)	3.5efg
27	Harmony	1.0g
28	Harmony + Vydate (55kg)	0.5g
LSD (P=.05)		7.81
Standard Deviation		4.78
CV		72.97
Replicate F		4.834
Replicate Prob(F)		0.0117
Treatment F		4.613
Treatment Prob(F)		0.0001

Means followed by same letter do not significantly differ (P=.05, LSD)

4.3. 2012 Trial

TABLE 12 - PCN LEVELS IN THE TRIAL AREA (PI) – SAMPLED 11.05.2012

Sample area	Total cysts/100g soil	eggs/g soil
Block 1	52	16
Block 2	58	24
Block 3	56	23

Initial PCN levels showed an even infestation over the trial area, allowing comparison between nematicide-treated plots and untreated plots. The high numbers of cysts present in all samples indicated a long-standing infestation.

TABLE 12A - SPECIATION OF PCN IN TRIAL AREA.

Characteristic band patterns of:	
Globodera pallida (%)	*Globodera rostochiensis* (%)
100	0

PCN speciation was determined using DNA assay techniques (work conducted by NIAB Labtest, Cambridge). The trial area contained a single species PCN population of *Globodera pallida*.

4.3.1. Crop vigour (haulm volume / % ground cover).

Crop vigour assessments are shown in Table 13 and Figures 11 and 12 below.

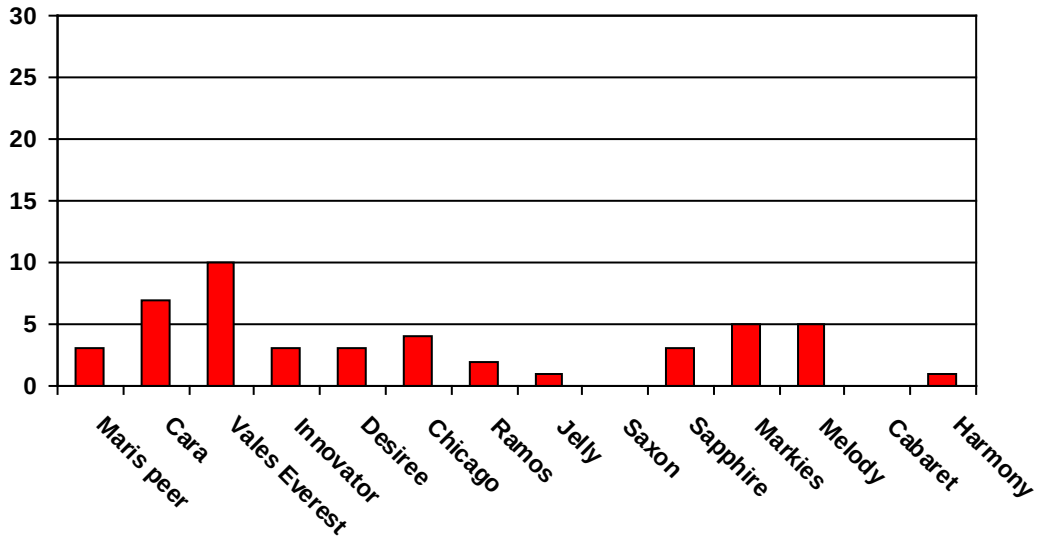

FIGURE 11. EFFECT OF NEMATICIDE ON INCREASE IN % CROP GROUND COVER 17.06.2012

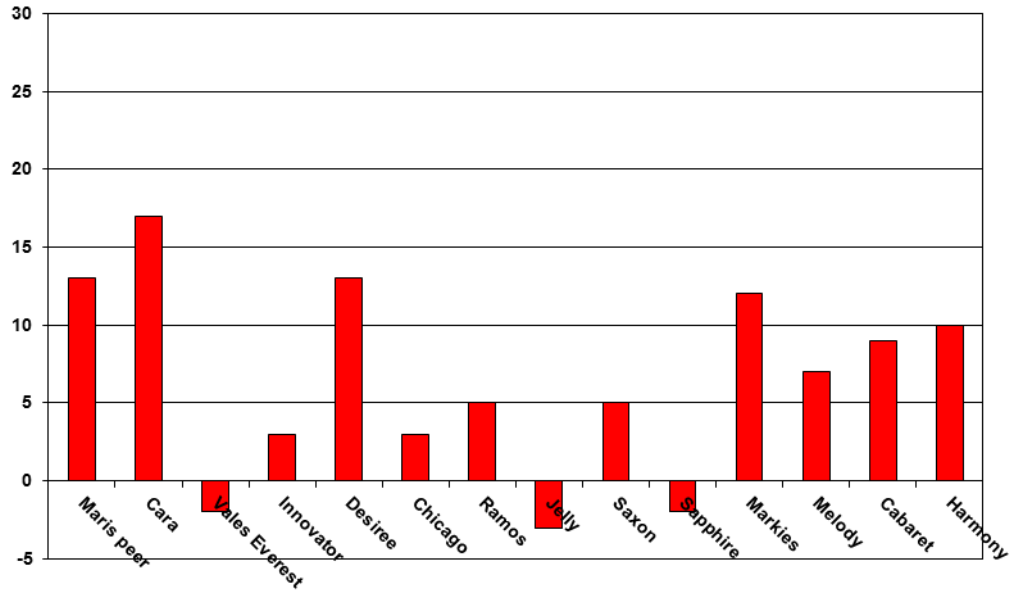

FIGURE 12 – EFFECT OF NEMATICIDE ON INCREASE IN % CROP GROUND COVER 13.07.2012

Use of nematicide increased crop vigour (13.07.2012) in all varieties except Vales Everest, Sapphire and Jelly, most of these vigour increases were not significant (Table 13; P=0.05). Only Cara showed a significant (P=0.05) increase in haulm vigour due to the use of nematicides. This finding is in complete contrast to earlier findings which indicated that Cara was one of the most tolerant varieties trialled and consequently showed the least increase in haulm vigour due to use of nematicides. However, haulm vigour differences were not always a good indicator of similar differences in yield.

TABLE 13 – CROP VIGOUR (% GROUND COVER) ASSESSED 17.06.2012 AND 13.07.2012.

Part Rated		Haulm -		Haulm -	
Rating Date		Jun-17-2012		Jul-13-2012	
Rating Type		Groundcover		Groundcover	
Rating Unit		%		%	
Trt	Treatment Name				
1	Maris Peer	14	d-h	50	gh
2	Maris Peer + Vydate (55kg)	17	cde	63	efg
3	Cara	25	b	80	bcd
4	Cara + Vydate (55kg)	32	a	97	a
5	Vales Everest	17	cde	85	ab
6	Vales Everest + Vydate (55kg)	27	ab	83	abc
7	Innovator	6	i	47	h
8	Innovator + Vydate (55kg)	9	f-i	50	gh
9	Desiree	15	c-g	57	fgh
10	Desiree + Vydate (55kg)	18	cd	70	c-f
11	Chicago	12	d-i	75	b-e
12	Chicago + Vydate (55kg)	16	c-f	78	bcd
13	Ramos	8	ghi	78	bcd
14	Ramos + Vydate (55kg)	10	e-i	83	abc
15	Jelly	14	d-h	80	bcd
16	Jelly + Vydate (55kg)	15	c-g	77	b-e
17	Saxon	14	d-h	58	fgh
18	Saxon + Vydate (55kg)	14	d-h	63	efg
19	Sapphire	12	d-i	85	ab
20	Sapphire + Vydate (55kg)	15	c-g	83	abc
21	Markies	17	cde	83	abc
22	Markies + Vydate (55kg)	22	bc	95	a
23	Melody	12	d-i	70	c-f
24	Melody + Vydate (55kg)	17	cde	77	b-e
25	Cabaret	15	c-g	68	def
26	Cabaret + Vydate (55kg)	15	c-g	77	b-e
27	Harmony	7	hi	53	gh
28	Harmony + Vydate (55kg)	8	f-i	63	efg
LSD (P=.05)		6.1		11.6	
Standard Deviation		3.7		7.1	
CV		24.65		9.83	
Replicate F		0.791		4.028	
Replicate Prob(F)		0.4588		0.0234	
Treatment F		7.345		10.707	
Treatment Prob(F)		0.0001		0.0001	

Means followed by same letter do not significantly differ (P=.05, LSD)

4.3.2. Potato yield and grade.

Nematicide application resulted in a yield increase in all varieties except Jelly; few of these yield increases were significant (P=0.05). The use of nematicides did not raise yields as much as in most previous trials. Very wet soil conditions during the season probably limited the efficacy of the nematicide.

The “standard” varieties for PCN tolerance, Maris Peer and Cara, did not behave as expected and the yield responses of other varieties, sometimes differed from previous trials. The exceptional weather conditions and the weather-imposed delay between nematicide application and planting, may have seriously compromised the usefulness of 2012 tolerance data.

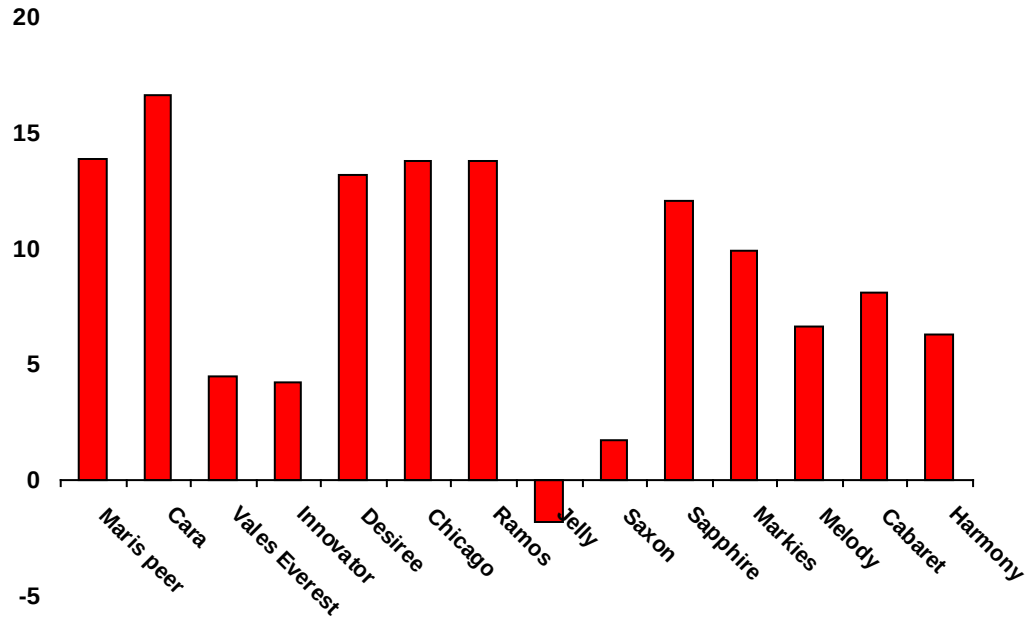

FIGURE 13. EFFECT OF NEMATICIDE ON % INCREASE IN TOTAL YIELD.

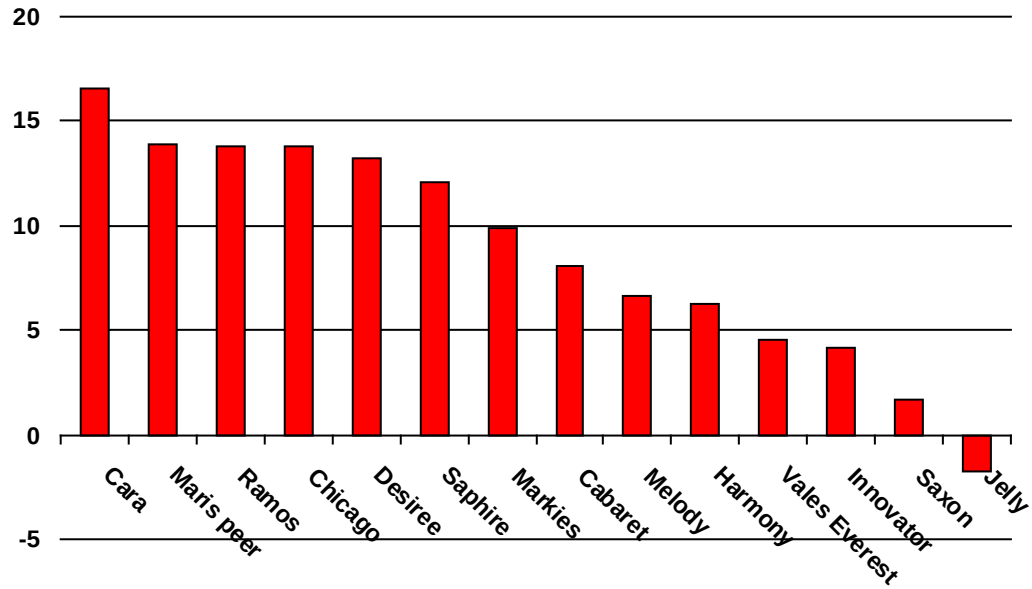

FIGURE 14 - EFFECT OF NEMATICIDE ON % INCREASE IN TOTAL YIELD (RANKED DATA).

TABLE 14 – EFFECT OF NEMATICIDE ON YIELD AND GRADE OF POTATOES (T/HA).

Part Rated		Tuber -	Tuber -	Tuber -	Tuber -
Rating Date		Sep-29-2012	Sep-29-2012	Sep-29-2012	Sep-29-2012
Rating Type		<45mm	45-60mm	>60mm	Total Yield
Rating Unit		t/ha	t/ha	t/ha	t/ha
Trt	Treatment Name				
1	Maris Peer	11.7 a-e	3.5 m	0.0 g	15.1 j
2	Maris Peer + Vydate (55kg)	5.9 g-m	11.0 jkl	0.2 g	17.2 ij
3	Cara	6.2 g-l	22.9 bcd	25.7 c	54.7 a
4	Cara + Vydate (55kg)	5.0 i-n	23.8 bc	35.0 b	63.8 a
5	Vales Everest	1.6 n	10.9 jkl	45.1 a	57.5 a
6	Vales Everest + Vydate (55kg)	1.8 mn	12.1 h-l	46.2 a	60.1 a
7	Innovator	1.8 mn	11.0 jkl	13.1 d	25.9 f-i
8	Innovator + Vydate (55kg)	1.9 mn	13.5 g-k	11.7 de	27.0 e-h
9	Desiree	9.5 b-h	7.6 klm	0.2 g	17.4 ij
10	Desiree + Vydate (55kg)	10.1 b-g	8.3 klm	1.3 g	19.7 hij
11	Chicago	5.7 h-n	25.6 ab	4.3 efg	35.6 b-e
12	Chicago + Vydate (55kg)	6.7 f-k	30.1 a	4.5 efg	41.3 bc
13	Ramos	8.0 e-i	21.5 b-e	7.5 d-g	37.0 bcd
14	Ramos+ Vydate (55kg)	10.8 b-f	20.5 b-f	10.8 def	42.1 b
15	Jelly	8.5 d-i	20.3 b-f	9.9 def	38.7 bcd
16	Jelly + Vydate (55kg)	9.0 c-i	21.3 b-e	7.7 d-g	38.0 bcd
17	Saxon	7.3 f-j	13.0 g-l	3.6 efg	23.9 g-j
18	Saxon + Vydate (55kg)	8.4 d-i	13.5 g-k	2.5 fg	24.3 ghi
19	Sapphire	2.2 lmn	17.0 d-j	36.7 b	56.0 a
20	Sapphire + Vydate (55kg)	2.7 k-n	18.4 c-h	41.7 ab	62.8 a
21	Markies	13.6 ab	16.7 d-j	4.0 efg	34.3 b-f
22	Markies + Vydate (55kg)	15.6 a	18.8 c-g	3.3 fg	37.7 bcd
23	Melody	13.1 abc	14.9 f-j	2.5 fg	30.5 d-g
24	Melody + Vydate (55kg)	12.6 a-d	17.2 d-j	2.8 fg	32.5 c-g
25	Cabaret	7.9 e-j	15.7 e-j	6.3 d-g	29.8 d-g
26	Cabaret + Vydate (55kg)	9.8 b-h	17.5 c-i	4.9 efg	32.2 c-g
27	Harmony	3.7 j-n	7.0 lm	24.0 c	34.7 b-f
28	Harmony + Vydate (55kg)	2.6 k-n	11.2 i-l	23.1 c	36.9 bcd
LSD (P=.05)		3.59	5.38	6.91	8.02
Standard Deviation		2.20	3.29	4.23	4.91
CV		30.23	20.73	31.28	13.4
Replicate F		3.069	3.009	0.575	6.253
Replicate Prob(F)		0.0546	0.0577	0.5663	0.0036
Treatment F		10.152	10.447	36.865	24.495
Treatment Prob(F)		0.0001	0.0001	0.0001	0.0001

Means followed by same letter do not significantly differ (P=.05, LSD)

4.3.3. PCN population dynamics.

Use of a nematicide has reduced the PCN population increase (Pf:Pi) for all varieties except Ramos, Jelly, Cabaret and Sapphire. However, none of these Pf:Pi reductions are significant (P=0.05). Variety greatly influenced the PCN population increase (Pf:Pi), both in the presence and especially in the absence, of a nematicide.

PCN population dynamics were very untypical compared with results from other trials in past seasons. For example, PCN increases after cropping, regardless of nematicide use, were very low. Cara providing the greatest increase in PCN with Pf:Pi of only 3.5. Most other varieties only showed Pf:Pi ratios of less than 2.0 with little difference between untreated and nematicide treated plots. The growing of Vales Everest, Innovator and Harmony, caused a reduction in the level of *G. pallida* in the soil whether treated with a nematicide or untreated.

The general effect of varieties on PCN population dynamics followed a similar pattern to previous seasons, although the actual Pf:Pi values were very different to previous trials. The effect of an exceptionally wet and cold season appears to have reduced both potato yield and PCN proliferation.

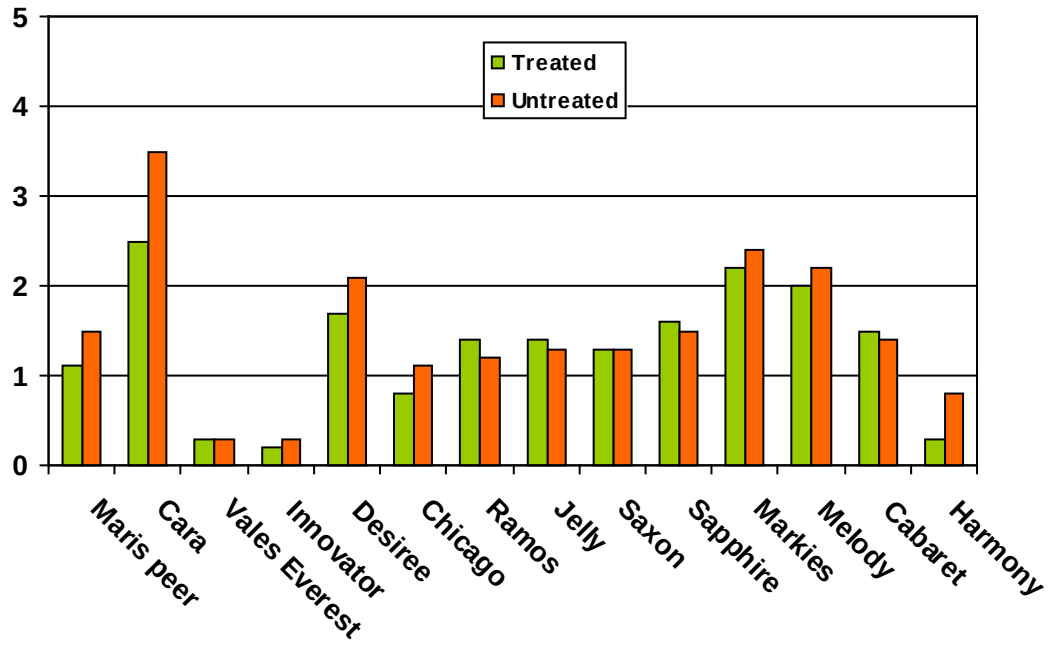

FIGURE 15. EFFECT OF VARIETY AND NEMATICIDE ON PCN POPULATION DYNAMICS (PF:PI).

TABLE 15 – THE EFFECT OF VARIETY AND NEMATICIDE ON PCN POPULATION DYNAMICS (PF:PI).

Part Rated		Soil	-
Rating Date		Sep-29-2012	
Rating Type		Pf:Pi ratio	
Rating Unit			
Trt	Treatment		
1	Maris Peer	1.5	b-f
2	Maris Peer + Vydate (55kg)	1.1	c-g
3	Cara	3.5	a
4	Cara + Vydate (55kg)	2.5	ab
5	Vales Everest	0.3	fg
6	Vales Everest + Vydate (55kg)	0.3	fg
7	Innovator	0.3	fg
8	Innovator + Vydate (55kg)	0.2	g
9	Desiree	2.1	bcd
10	Desiree + Vydate (55kg)	1.7	b-e
11	Chicago	1.1	c-g
12	Chicago + Vydate (55kg)	0.8	d-g
13	Ramos	1.2	b-g
14	Ramos+ Vydate (55kg)	1.4	b-g
15	Jelly	1.3	b-g
16	Jelly + Vydate (55kg)	1.4	b-g
17	Saxon	1.3	b-g
18	Saxon + Vydate (55kg)	1.3	b-g
19	Sapphire	1.5	b-f
20	Sapphire + Vydate (55kg)	1.6	b-e
21	Markies	2.4	b
22	Markies + Vydate (55kg)	2.2	bc
23	Melody	2.2	bc
24	Melody + Vydate (55kg)	2.0	b-e
25	Cabaret	1.4	b-g
26	Cabaret + Vydate (55kg)	1.5	b-f
27	Harmony	0.8	efg
28	Harmony + Vydate (55kg)	0.3	fg
LSD (P=.05)		1.06	
Standard Deviation		0.65	
CV		46.35	
Replicate F		8.104	
Replicate Prob(F)		0.0008	
Treatment F		4.435	
Treatment Prob(F)		0.0001	

Means followed by same letter do not significantly differ (P=.05, LSD)

4.4. Over years' results

4.4.1. Tolerance

The comparison of yield loss, calculated from yield data from the vydate-treated and untreated plots, over the three years* of trials for each variety is provided in Figure 16. (*Sierra Gold was not included in the trials in 2012).

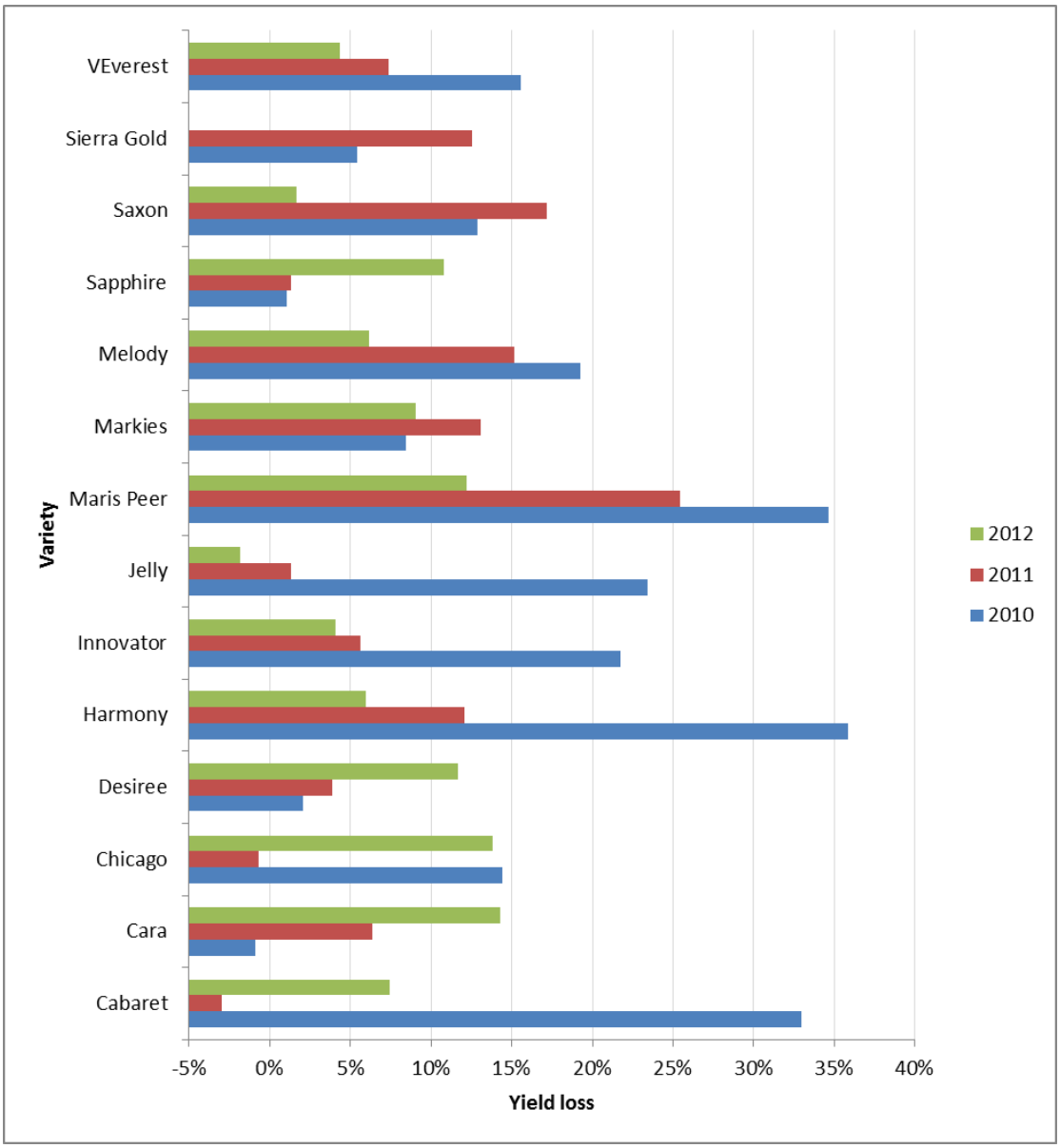

FIGURE 16. PER CENT YIELD LOSS FOR EACH VARIETY DURING THE THREE YEARS' TRIALS.

4.4.2. PCN population dynamics

The Pf/Pi value for each variety (calculated from data for the untreated plots) in each of the three years of trials* is provided in Figure 17. (*Sierra Gold was not included in the trials in 2012).

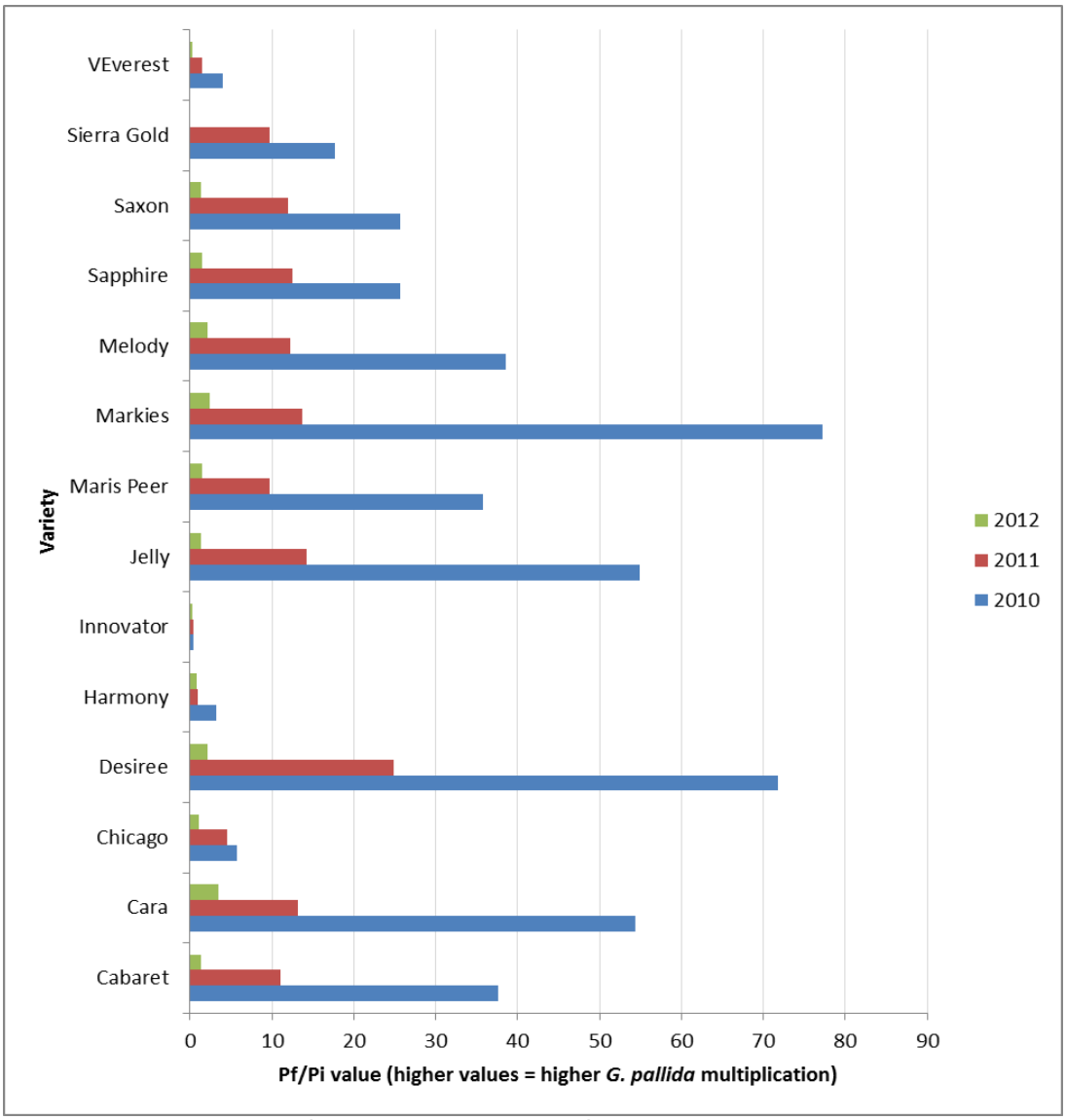

FIGURE 17. PCN MULTIPLICATION (IN THE UNTREATED PLOTS) IN EACH OF THE THREE YEARS' TRIALS.

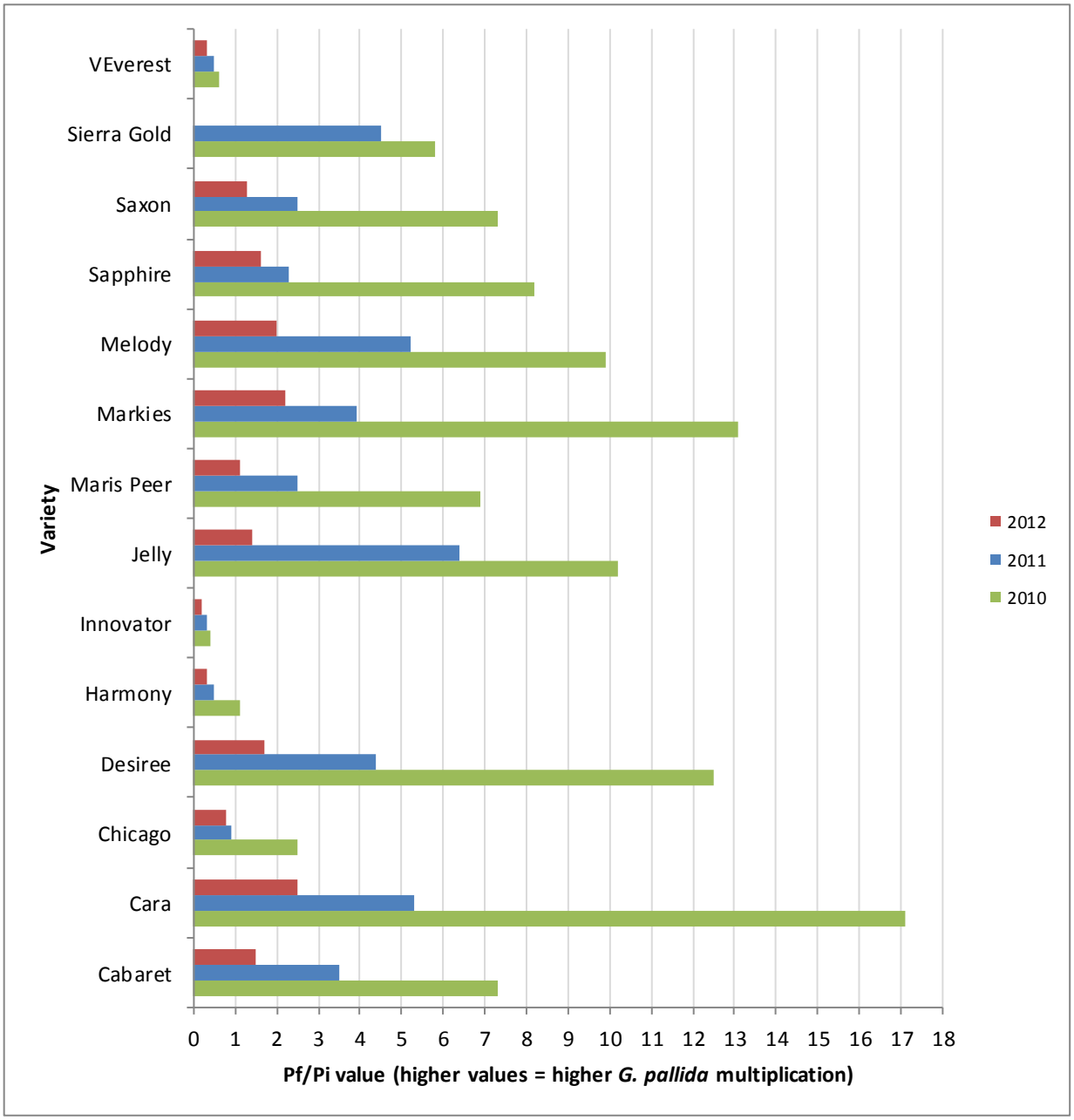

FIGURE 18. PCN MULTIPLICATION (IN THE VYDATE-TREATED PLOTS) IN EACH OF THE THREE YEARS' TRIALS.

5. DISCUSSION

Tolerance is an important agronomic trait allowing viable potato yields to be grown in PCN infested soil. Previously, tolerance was determined using pot trials. Extrapolation of tolerance from pot data to a field grown crop is far more difficult compared to the field-based method employed in this study. The only slight disadvantage of a field-based method versus a pot test is that external factors, such as weather conditions, are unable to be controlled.

The weather during the 2010 growing season could be described as average for south Lincolnshire. The "standard" varieties for PCN tolerance behaved in line with expectation. Maris Peer showed a large yield increase due to the nematicidal control of PCN, whereas the Cara yield was almost unaffected by nematicide use. Harmony and Cabaret also showed a big yield increase due to PCN control and would be described as very intolerant. The varieties Jelly, Melody, Innovator, Vales Everest,

Chicago Saxon and Markies all showed intermediate yield responses to nematicide use and would be classed as intolerant. Sierra Gold, Desiree and Sapphire all gave the least response to nematicide and would be described as tolerant.

2011 was one of the driest growing seasons on record. Such severe dry conditions would be expected to greatly affect the interaction between the crop, PCN and nematicide control. A nematicide relies on sufficient soil water to dissolve the active ingredient and prevent PCN juveniles from affecting potato root systems. Therefore the yield differences between nematicide treated and untreated crops are likely to be reduced due to impaired nematicide activity. Largely as a consequence of the unusual weather conditions, there was little difference between the tolerances of the varieties. Because weather conditions masked tolerance differences in 2011 it was not possible to assign tolerance classes, using 2011 data.

The weather conditions of 2012 were also very extreme. This season was one of the wettest on record. Abnormally wet conditions also affect the interaction between crop, PCN and nematicide control. Continually wet soil conditions can cause leaching of nematicide with a consequent reduction in efficacy. Poor nematicide efficacy will mask the effect of varietal tolerance. An additional problem this season was the delay between nematicide application and planting. This delay was due to waterlogged soil conditions immediately after nematicide incorporation. This would have resulted in nematicide breakdown before the crop was planted and a consequent loss of efficacy.

To further complicate interpretation of tolerance data, light levels were exceptionally low which resulted in low yields across all varieties. Low light caused a yield plateau in 2012 which could have prevented the full expression of tolerance traits. Unfortunately, these extreme weather conditions resulted in atypical performance of the “standard” varieties which greatly diminished the reliability of 2012 tolerance data.

Resistance to PCN is another very important agronomic trait, useful for managing PCN levels. Some of the varieties in this project were chosen for their claimed resistance to *G. pallida.* Fortunately, this trait is far less affected by weather conditions and consistent data was obtained over the three year period

When Innovator, Harmony and Vales Everest were grown in conjunction with a nematicide, a decrease in *G. pallida* levels was observed in all trials over the 2010 – 2012 period. Even where these varieties were grown in the absence of nematicides, PCN levels were either reduced or remained at pre-growing levels. These findings have huge implications for future PCN management, especially if nematicide use is curtailed by regulation.

The “holy grail” of sustainable PCN management would be to develop varieties with a combination of good resistance and tolerance levels. Such varieties would allow production of viable yields in PCN infested soil whilst offering reduction of *G. pallida* levels. However, PCN monitoring must continue to check for PCN pathotypes which may be on selected by varietal resistance specific to certain current PCN pathotypes.

Some new varieties are claiming this combination of tolerance and resistance traits. Future work should concentrate on evaluating these varieties. This line of development work is especially important for the future of UK potato production, given the regulatory doubts surrounding future nematicide use.

6. REFERENCES

Arntzen FK & TCAE Wouters. 1994. Assessing the tolerance to *Globodera pallida* of resistant potato genotypes by means of field and pot tests. Potato Research 37(1): 51-63.