



A field trial investigating the resistance and tolerance characteristics of eight potato varieties to *Globodera pallida* in Scotland.

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Introduction

Delivering a sustainable potato industry for Scotland through management of Potato cyst nematode (PCN) is a project managed by the Plant Health Centre with Scottish Government funding. On the 8th of August 2023 the open day for the second year of field trials for the PCN Action Scotland project was held. This field trial is part of a multi-year project to provide data on the integrated control of *Globodera pallida* (Project Work package 7) and to continue with knowledge exchange between the project and wider potato industry (Project Work package 8). The field trials are also an excellent opportunity to gather data for both work package 2 (Decision Support System) and work package 5 (Tolerance). Over one hundred growers, agronomists, and potato breeders attended the open day for the 2023 field trial. At this event attendees also engaged with other work package leaders and outputs. This report brings together all the data and analysis from this trial. This work builds upon the 2022 trial by adding a second chemical active. This was through incorporating treatments to varieties with Velum Prime, as well as those treated with Nemathorin. Certain varieties have also been changed since the 2022 line up – Cara, Innovator, Maris Peer, Cinderella, and Tyson have been replaced by Maris Piper and Paradox.

As this is the second year of the trial it is important to report on varying weather conditions which may have contributed to differences in data as well. In 2023 the trial was delayed in

being planted until the 3rd of May due to wet spring conditions with many lingering frosts. May into June saw dry soil conditions. September into early October (immediately prior to harvest on 10th October) were wetter than average. In comparison the 2022 growing season was much dry and warmer. In general there was an earlier start to planting and less rainfall throughout the season. The difference in rainfall in 2023 may contribute somewhat to explaining some of the internal defects observed. Although the data collected throughout the project is sound, we advise caution is taken in extrapolating from field samples from a single year given the unusual weather conditions experienced in 2023. **All statistical analysis was carried out using ANOVA tests. A copy of the following data including ad hoc statistics attached is available on request.**

Field trial design

A field trial was planted at Barnyards Farm (Grid reference 480 576) on 03/05/2023 – a location with a moderate to high PCN population. The trial consisted of eight potato varieties. Replicates of each variety were planted and treated with either Nemathorin 10G (30 kg/ha, a.i. fosthiazate), Velum Prime (0.625 L/ha in furrow a.i. fluopyram) or left untreated. All seed was treated with Rhino DSG (2 kg/t) prior to planting. All inputs into the trial were applied by the host grower and followed standard practice for ware crops in the region. The trial was flailed on 26/08/2023 and treated with Spotlight plus (1.0 l/ha) on 03/09/2023 before harvest on 10/10/2023.

Varieties

Details of the varieties including breeder, parentage, maturity, and the seed spacing used in this trial are given in Table 1. The variety characteristics, including resistance to key PCN species, which have been collated from multiple sources including the AHDB potatoes potato variety database (<https://potatoes.agricrops.org/>) and information held by breeders themselves is given in Table 2.

Table 1 – Trial varieties, breeder, parentage, maturity, and seed tube spacing used.

Variety	Breeder	Parentage	Maturity	Seed spacing
Maris Piper	PBI Cambridge	(CPC 1673 x Ulster Knight) x (Arran Cairn x Herald)	Main crop	44 cm
Elland	Cygnets	Golden Millenium x Innovator	Early maincrop	32 cm
Eurostar	Stet	Victoria x Innovator	Main crop	31 cm
Buster	IPM	Innovator x ET5838/8	Late Maincrop	29 cm
Amanda	Solana	Epoka x SV66 123	Medium early	43 cm
Karelia	Europlant (Greenvale)	III 61659230 x Wentow 58 7 49	Medium early	25 cm
Lanorma	Branston	Bydand x Caesar	Early maincrop	24 cm
Paradox	IPM	Amanda x Orla	Late maincrop	40 cm

Table 2 – Pest and disease resistance of varieties (Data from range of sources). 1: Highly susceptible – 9: Highly Resistant, S – Susceptible, R – Resistant.

Variety	Disease/Pest resistance (scale 1 – 9)				
	G. <i>rostochiensis</i>	G. <i>pallida</i>	Powdery scab	Blackleg	Common scab
Maris Piper	9	2	3	5	1
Elland	3	9	4	6	6
Eurostar	9	9	4	4	5
Buster	9	9	4	6	7
Amanda	9	8	7	6	7
Karelia	8	8		High	Low
Lanorma	9	5	4	4	7
Paradox	2	7	5	6	4

Assessments

Assessments were made before planting, during emergence and ground cover development, at harvest, and post-harvest.

Initial PCN population (P_i) at planting: Soil (500 g) was sampled from each individual plot before planting. These were assessed by the SRUC crop clinic to determine the initial number of cysts and eggs present and expressed as number of viable cysts and eggs per gram of soil.

Crop emergence: The emergence of each plot was assessed on 02/06/2023, 08/06/2023, and 12/06/2023 and expressed as the number of plants per 6 m of drill.

Potato foliage groundcover: The ground cover in each plot was assessed visually on 12/06/2023, 20/06/2023, 27/06/2023, 03/07/2023, 10/07/2023, and 18/07/2023 and expressed as a percentage.

Number of plants and stems: After haulm destruction a count was taken of the number of plants and stems present in 3 m drill lengths of each plot. This was assessed on the 10/10/2023. The results were expressed as number of plants and stems per 3 m length.

Dry matter and density: This was assessed by hygrometer for tuber samples from each plot and results were expressed as a percentage dry matter and relative density. This was assessed on the 24/10/2023.

Post harvest PCN population (P_f): Soil (500 g) was sampled from each individual plot after harvest. These samples were assessed by SRUC crop clinic to determine the number of cysts and eggs present and expressed as number of viable cysts and eggs per gram of soil.

Tuber yield and number: The central two drills of each plot were harvested. The harvested tubers were graded into different size fractions (<25 mm, 25–30 mm, 30–35 mm, 35–40 mm, 40–45 mm, 45–50 mm, 50–55 mm, 55–60 mm, 60–65 mm, 65–70 mm, 70–75 mm, 75–80 mm, 80–85 mm, and >85 mm) using a ‘smartgrader’ with the yield and tuber number in each size fraction determined. Results were expressed as tonnes/ha and tubers per ha. Total yield and tuber number was determined.

Internal defects (rots, spraing, hollow heart, internal rust spot, and watery wound rot): fifty tuber samples were sliced to record the frequency of internal defects by Scottish Agronomy. Results are expressed as percentage of tubers with internal disease present.

Tuber skin finish and surface disease: Samples of fifty tubers were retained in an ambient store and assessed in December 2023. The tubers were washed and assessed for the presence of common scab (*Streptomyces scabies* spp.), powdery scab (*Spongospora subterranea*), black scurf (*Rhizoctonia solani*), Silver scurf (*Helminthosporium solani*) and black dot (*Colletotrichum coccodes*). Tubers were also assessed for splits and netting. Results are expressed as the percentage of tubers with infection (% incidence) and the average severity scores (scale of 0–3).

PCN Action Scotland open day photographs, Barnyards – 8th August 2023



Results

Crop emergence and ground cover

Significant differences in the emergence of different varieties were observed. For example, Maris Piper had 10.1 plants per 6 m emerged by the 12th of June compared to Karelia which had 21.3 plants emerged by that date. Contrasting emergence can be influenced by multiple factors such as standard varietal differences, seed size used, physiological age of the seed stock, how well sprouted tubers were prior to planting, and chemical input. Generally, Velum Prime treatment resulted in a significant increase in emergence when compared to untreated reps (when results were averaged across varieties) (Figure 1). Velum prime had 16.4 plants per 6-meter zone emerged by the 12th of June compared to 15.8 in the untreated reps. There was no significant difference between Nemathorin treatments (15.8) and the untreated reps. This is a change on 2022 trial data which showed Nemathorin producing a significant increase in emergence while Velum Prime did not. There were no significant differences observed between the emergence of individual varieties in response to Nemathorin or Velum Prime treatments except in the case of Lanorma (Table 3). Untreated Lanorma plots had 15 plants per 6-meter zone emerged by the 12th of June compared to 18.5 for Velum Prime, and 17.3 for Nemathorin treatments. The early growth of potatoes is mostly reliant upon reserves present within the mother tuber and at this early growth stage is generally unaffected by the presence of PCN.

Later observations of ground cover development (percentage) were found to vary between varieties and in response to the application of Nemathorin or Velum Prime (Appendix 1). There's no statistically significant interaction between variety and nematicide usage. Although there are statistically significant differences in ground cover for certain varieties at certain sampling dates, overall there is no significant difference to groundcover caused by the application of either nematicide. As a trend the nematicides do marginally improve ground cover but varietal differences accounts for more.

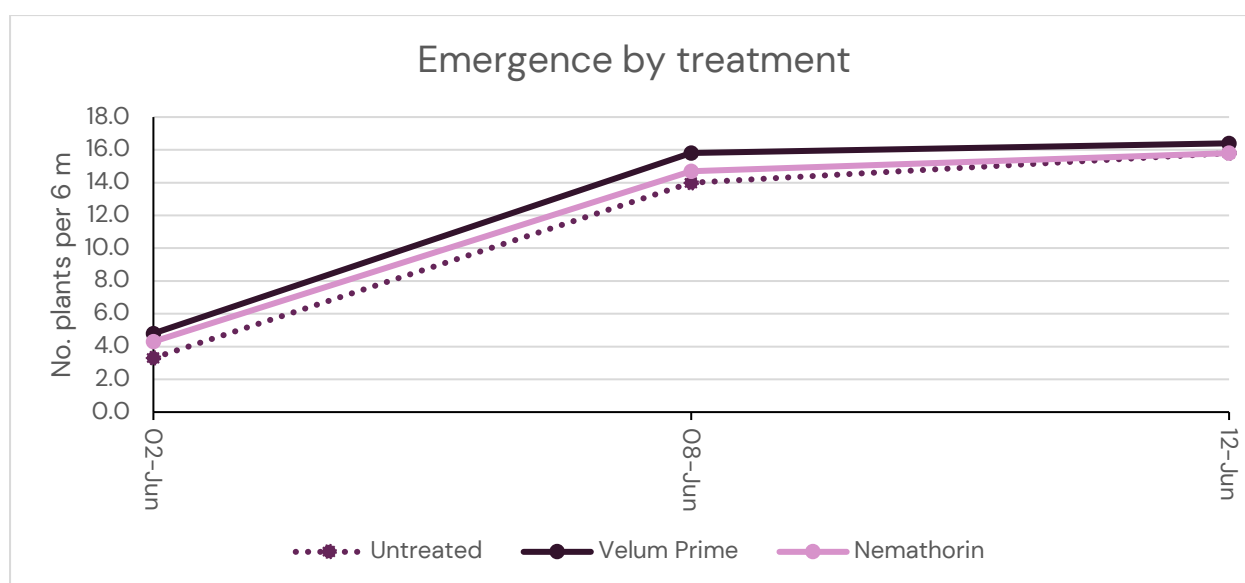


Figure 1 – Emergence by treatment – untreated, Velum Prime, and Nemathorin across three dates in June.

Table 3 – Crop emergence and ground cover at a range of dates during early and mid-growing season

Variety	Emergence			Ground Cover					
	02/06/2023	08/06/2023	12/06/2023	12/06/2023	20/06/2023	27/06/2023	03/07/2023	10/07/2023	18/07/2023
	N°/6m	N°/6m	N°/6m	%	%	%	%	%	%
Maris Piper	2.8	9.2	10.1	6.4	12.9	36.3	36.3	66.7	77.9
Elland	4.1	16.4	17.8	7.7	15.3	43.8	39.6	67.1	71.3
Karelia	6.1	21.6	21.3	7.3	16.8	45.8	42.1	67.1	71.3
Buster	0.7	15.8	17.8	5.7	13.8	42.5	31.7	66.3	65.8
Amanda	12.6	13.6	13.3	13.3	22.0	52.1	52.1	73.3	81.3
Eurostar	1.9	15.7	16.9	6.8	17.3	47.1	51.7	75.8	90.8
Lanorma	1.7	13.3	16.9	5.7	13.1	42.9	39.4	71.7	83.3
Paradox	3.3	13.3	14.0	7.7	15.5	43.8	44.2	71.7	77.5
LSD P=.05	1.75	1.31	0.90	1.23	2.41	4.53	5.53	6.01	4.75
Standard Deviation	2.15	1.60	1.10	1.51	2.96	5.56	6.79	7.38	5.83
CV	52.20	10.80	6.87	19.91	18.71	12.56	16.12	10.55	7.53

Treatment	Emergence			Ground Cover					
	02/06/2023	08/06/2023	12/06/2023	12/06/2023	20/06/2023	27/06/2023	03/07/2023	10/07/2023	18/07/2023
	N°/6m	N°/6m	N°/6m	%	%	%	%	%	%
Untreated	3.3	14.0	15.8	6.6	13.9	41.4	38.8	68.3	74.2
Velum Prime	4.8	15.8	16.4	8.3	17.0	47.5	44.5	71.7	78.9
Nemathorin	4.3	14.7	15.8	7.8	16.5	43.9	43.1	69.8	79.1
LSD P=.05	1.07	0.80	0.55	0.75	1.48	2.77	3.39	3.68	2.91
Standard Deviation	2.15	1.60	1.10	1.51	2.96	5.56	6.79	7.38	5.83
CV	52.20	10.80	6.87	19.91	18.71	12.56	16.12	10.55	7.53

Variety + Treatment	Emergence			Ground Cover					
	02/06/2023	08/06/2023	12/06/2023	12/06/2023	20/06/2023	27/06/2023	03/07/2023	10/07/2023	18/07/2023
	N°/6m	N°/6m	N°/6m	%	%	%	%	%	%
Maris Piper Untreated	2.0	8.5	10.0	5.5	11.8	35.0	38.8	67.5	80.0
Maris Piper Velum Prime	3.0	9.5	10.5	7.3	13.5	38.8	37.5	71.3	77.5
Maris Piper Nemathorin	3.3	9.5	9.8	6.5	13.5	35.0	32.5	61.3	76.3
Elland Untreated	1.5	14.3	17.5	6.0	12.3	41.3	36.3	67.5	65.0
Elland Velum Prime	5.5	18.0	18.5	8.5	18.0	47.5	41.3	70.0	73.8
Elland Nemathorin	5.3	17.0	17.3	8.5	15.5	42.5	41.3	63.8	75.0
Karelia Untreated	5.0	21.5	21.3	6.5	15.5	43.8	36.3	63.8	67.5
Karelia Velum Prime	5.8	21.5	21.5	7.8	16.8	48.8	43.8	66.3	72.5
Karelia Nemathorin	7.5	21.8	21.3	7.8	18.0	45.0	46.3	71.3	73.8
Buster Untreated	0.0	13.0	18.0	5.0	11.0	40.0	28.8	67.5	61.3
Buster Velum Prime	1.0	18.0	17.8	6.0	14.8	43.8	31.3	68.8	63.8
Buster Nemathorin	1.0	16.5	17.5	6.0	15.5	43.8	35.0	62.5	72.5
Amanda Untreated	12.5	13.5	13.5	12.5	20.5	48.8	48.8	76.3	78.8
Amanda Velum Prime	13.3	13.8	13.3	13.8	21.8	55.0	53.8	68.8	81.3
Amanda Nemathorin	12.0	13.5	13.0	13.8	23.8	52.5	53.8	75.0	83.8
Eurostar Untreated	0.8	15.3	17.5	6.0	16.3	42.5	46.3	72.5	88.8
Eurostar Velum Prime	3.8	16.8	17.3	8.5	18.0	52.5	56.3	73.8	93.8
Eurostar Nemathorin	1.3	15.0	16.0	6.0	17.5	46.3	52.5	81.3	90.0
Lanorma Untreated	2.3	13.8	15.0	5.0	11.5	40.0	37.5	66.3	81.3
Lanorma Velum Prime	1.3	15.5	18.5	6.5	15.5	46.3	43.8	76.3	87.5
Lanorma Nemathorin	1.5	10.8	17.3	5.5	12.3	42.5	37.0	72.5	81.3
Paradox Untreated	2.0	12.5	13.5	6.0	12.8	40.0	37.5	65.0	71.3
Paradox Velum Prime	4.8	13.5	14.0	8.5	17.5	47.5	48.8	78.8	81.3
Paradox Nemathorin	3.0	13.8	14.5	8.5	16.3	43.8	46.3	71.3	80.0
LSD P=.05	3.04	2.26	1.55	2.13	4.17	7.84	9.58	10.41	8.22
Standard Deviation	2.15	1.6	1.1	1.51	2.96	5.56	6.79	7.38	5.83
CV	52.2	10.8	6.87	19.91	18.71	12.56	16.12	10.55	7.53

Number of plants, stems, rots, dry matter, and density

The number of plants in each plot was a factor of the initial planting rate with the number of stems in each 3 m of drill length being dependent upon the planting density and the characteristics of the variety (Table 4). Significant differences were noted between varieties and in developing variety-specific agronomy recommendations these differences should be considered. There was no significant effect of Nemathorin or Velum Prime application on the number of plants. There was a significant difference between the number of stems on untreated plots (31.4) and those treated with Velum Prime (34.2). Nemathorin had no significant effect on stem number.

Table 4 – Number of plants and stems at the end of the season, dry matter, and density

Variety	Plants	Stems	Soft Rots		Dry Matter	Density
	10/10/2023 N°/3m	10/10/2023 N°/3m	10/10/2023* N°/3m	24/10/2023** N°/3m	24/10/2023 %	24/10/2023 1.065-1.110
Maris Piper	6.8	27.1	0.1	0	20.12	1.08
Elland	9.3	35.3	0.1	0.2	18.42	1.07
Karelia	11.6	33.9	0	0	17.18	1.07
Buster	9.8	24.7	0.1	0.7	17.00	1.07
Amanda	7.2	39.2	0	0	20.88	1.08
Eurostar	8.8	25.9	0.2	0.3	18.87	1.07
Lanorma	11.2	32.1	0.2	0.3	17.00	1.07
Paradox	7.5	39.2	0	0.2	18.20	1.07
LSD P=.05	0.65	4.28	0.21	0.34	0.51	0.00
Standard Deviation	0.80	5.25	0.26	0.42	0.63	0.00
CV	8.92	16.33	358.64	225.10	3.40	0.29

Treatment	Plants	Stems	Soft Rots		Dry Matter	Density
	10/10/2023 N°/3m	10/10/2023 N°/3m	10/10/2023* N°/3m	24/10/2023** N°/3m	24/10/2023 %	24/10/2023 1.065-1.110
Untreated	9.0	31.4	0	0.2	18.53	1.07
Velum Prime	9.0	34.2	0.1	0.1	18.51	1.07
Nemathorin	9.0	30.9	0.2	0.3	18.34	1.07
LSD P=.05	0.40	2.62	0.13	0.21	0.31	0.00
Standard Deviation	0.80	5.25	0.26	0.42	0.63	0.00
CV	8.92	16.33	358.64	225.10	3.40	0.29

Variety & Treatment	Plants	Stems	Soft Rots		Dry Matter	Density
	10/10/2023 N°/3m	10/10/2023 N°/3m	10/10/2023* N°/3m	24/10/2023** N°/3m	24/10/2023 %	24/10/2023 1.065-1.110
Maris Piper Untreated	6.3	23.8	0	0	20.45	1.08
Maris Piper Velum Prime	7.3	29.0	0	0	19.85	1.08
Maris Piper Nemathorin	6.8	28.5	0.3	0	20.05	1.08
Elland Untreated	9.5	36.0	0	0	18.40	1.07
Elland Velum Prime	9.5	38.3	0	0	18.65	1.07
Elland Nemathorin	8.8	31.5	0.3	0.5	18.20	1.07
Karelia Untreated	11.8	35.0	0	0	17.15	1.07
Karelia Velum Prime	11.3	36.3	0	0	17.40	1.07
Karelia Nemathorin	11.8	30.5	0	0	17.00	1.07
Buster Untreated	10.0	23.5	0	1.0	17.00	1.07
Buster Velum Prime	9.5	27.8	0	0.3	17.00	1.07
Buster Nemathorin	10.0	22.8	0.3	0.8	17.00	1.07
Amanda Untreated	7.0	42.8	0	0	21.20	1.09
Amanda Velum Prime	6.8	37.8	0	0	21.20	1.09
Amanda Nemathorin	7.8	37.0	0	0	20.25	1.08
Eurostar Untreated	9.3	22.5	0	0.3	18.90	1.07
Eurostar Velum Prime	8.8	29.3	0.3	0.3	18.85	1.07
Eurostar Nemathorin	8.3	26.0	0.3	0.3	18.85	1.07
Lanorma Untreated	10.8	28.3	0	0.5	17.00	1.07
Lanorma Velum Prime	11.8	35.0	0.3	0	17.00	1.07
Lanorma Nemathorin	11.0	33.0	0.3	0.3	17.00	1.07
Paradox Untreated	7.5	39.3	0	0	18.15	1.07
Paradox Velum Prime	7.3	40.5	0	0.3	18.10	1.07
Paradox Nemathorin	7.8	37.8	0	0.3	18.35	1.07
LSD P=.05	1.13	7.41	0.37	0.60	0.88	0.00
Standard Deviation	0.80	5.25	0.26	0.42	0.63	0.00
CV	8.92	16.33	358.64	225.10	3.40	0.29

Note – * Number of soft rots in the 3m yield dig area, ** Number of soft rots in the yield bag at grading.

A small number of rots were present at harvest and at time of grading. There was no overall significant effect of Nemathorin or Velum Prime on the development of rots. The small number of rots recorded across different varieties and treatments were not considered to be of importance.

The dry matter (and related assessment of density) was, as expected, found to vary significantly between varieties. For three varieties (Karelia, Buster, and Lanorma) the dry matter was under 18%. This is in line with 2022 data as all three of these varieties have consecutively been under 18% dry matter. A low dry matter may result in poor taste and texture characteristics of some varieties for fresh market use while a high dry matter content can bring a susceptibility to bruising. Paradox, Eurostar, and Elland all sit between 18–19%. Interestingly Paradox is reported by the breeder as having a dry matter content of 21% so this trial data consistently underachieves this. Dry matter can be affected by maturity of the crop when it undergoes haulm destruction so predicting and achieving dry matter can be difficult. However, in this trial, the somewhat high Nitrogen rate applied (210 kg/ha) uniformly across all varieties and treatments is likely to have had a detrimental effect on dry matter

development and the development of variety-specific agronomy protocols should address this issue. In contrast, a high dry matter relative to other varieties for Maris Piper (20.12%) and Amanda (20.88%) might be considered too high for general pre-pack use. No significant differences in dry matter were observed due to Nemathorin or Velum Prime treatment.

Internal defects – Spraing, Hollow Heart, Internal rust spot (IRS) and Watery wound rot (WWR)

Spraing was observed in Buster and Lanorma at 1.2% each (LSD 0.62) (Table 5). In the 2022 trials application of Nemathorin resulted in a significant reduction in the incidence of Spraing (5.0% to 2.5%). This trend was not observed in the 2023 trials – In the four varieties where spraing was present Nemathorin only showed a significant impact for the variety Buster – no spraing was observed in the Nemathorin treated Buster when compared to 1.5% incidence in the Velum Prime treated plots and 2% in the untreated. There was also an increase in spraing in the Nemathorin treated plots, 3%, compared to 0% observed with Velum Prime and 0.5% in the untreated plots. Velum Prime had no significant impact on Spraing incidence rates.

Hollow heart, internal rust spot, and Water wound rot were observed at trace levels only (apart from Maris Piper – 3–4% hollow heart, 2–3% internal rust spot) with no significant difference between varieties or in response to Nemathorin or Velum Prime treatment. Internal defects pulled by variety show Maris Piper had the highest percentage incidence (Figure 2).

Table 5 – Incidence of Internal defects – Spraing, Hollow heart, Internal rust spot, and Watery wound rot.

Variety	Spraing 24/10/2023 %	Hollow Heart 24/10/2023 %	Internal Rust Spot 24/10/2023 %	Watery Wound Rot 24/10/2023 %
Maris Piper	0.2	3.3	2.3	0
Elland	0.3	0	0.5	0
Karelia	0	1.2	0.5	0
Buster	1.2	0.2	0.2	1.3
Amanda	0	0	0.3	0
Eurostar	0	0.7	0.3	0.2
Lanorma	1.2	0	0.2	0.2
Paradox	0	0	0.2	0.3
LSD P=.05	0.62	1.15	1.01	0.73
Standard Deviation	0.77	1.41	1.24	0.90
CV	216.43	211.36	221.25	359.28

Treatment	Spraing 24/10/2023 %	Hollow Heart 24/10/2023 %	Internal Rust Spot 24/10/2023 %	Watery Wound Rot 24/10/2023 %
Untreated	0.4	0.5	0.7	0.3
Velum Prime	0.3	0.8	0.3	0.3
Nemathorin	0.4	0.8	0.8	0.2
LSD P=.05	0.38	0.70	0.62	0.45
Standard Deviation	0.77	1.41	1.24	0.90
CV	216.43	211.36	221.25	359.28

Variety & Treatment	Spraing 24/10/2023 %	Hollow Heart 24/10/2023 %	Internal Rust Spot 24/10/2023 %	Watery Wound Rot 24/10/2023 %
Maris Piper Untreated	0.5	3.0	2.0	0
Maris Piper Velum Prime	0	4.0	2.0	0
Maris Piper Nemathorin	0	3.0	3.0	0
Elland Untreated	0	0	0.5	0
Elland Velum Prime	1.0	0	0	0
Elland Nemathorin	0	0	1.0	0
Karelia Untreated	0	1.0	1.5	0
Karelia Velum Prime	0	1.0	0	0
Karelia Nemathorin	0	1.5	0	0
Buster Untreated	2.0	0	0.5	2.0
Buster Velum Prime	1.5	0.5	0	1.0
Buster Nemathorin	0	0	0	1.0
Amanda Untreated	0	0	0	0
Amanda Velum Prime	0	0	0	0
Amanda Nemathorin	0	0	1.0	0
Eurostar Untreated	0	0	1.0	0
Eurostar Velum Prime	0	0.5	0	0.5
Eurostar Nemathorin	0	1.5	0	0
Lanorma Untreated	0.5	0	0	0
Lanorma Velum Prime	0	0	0	0
Lanorma Nemathorin	3	0	0.5	0.5
Paradox Untreated	0	0	0	0
Paradox Velum Prime	0	0	0	1.0
Paradox Nemathorin	0	0	0.5	0
LSD P=.05	1.08	1.99	1.76	1.27
Standard Deviation	0.77	1.41	1.24	0.90
CV	216.43	211.36	221.25	359.28

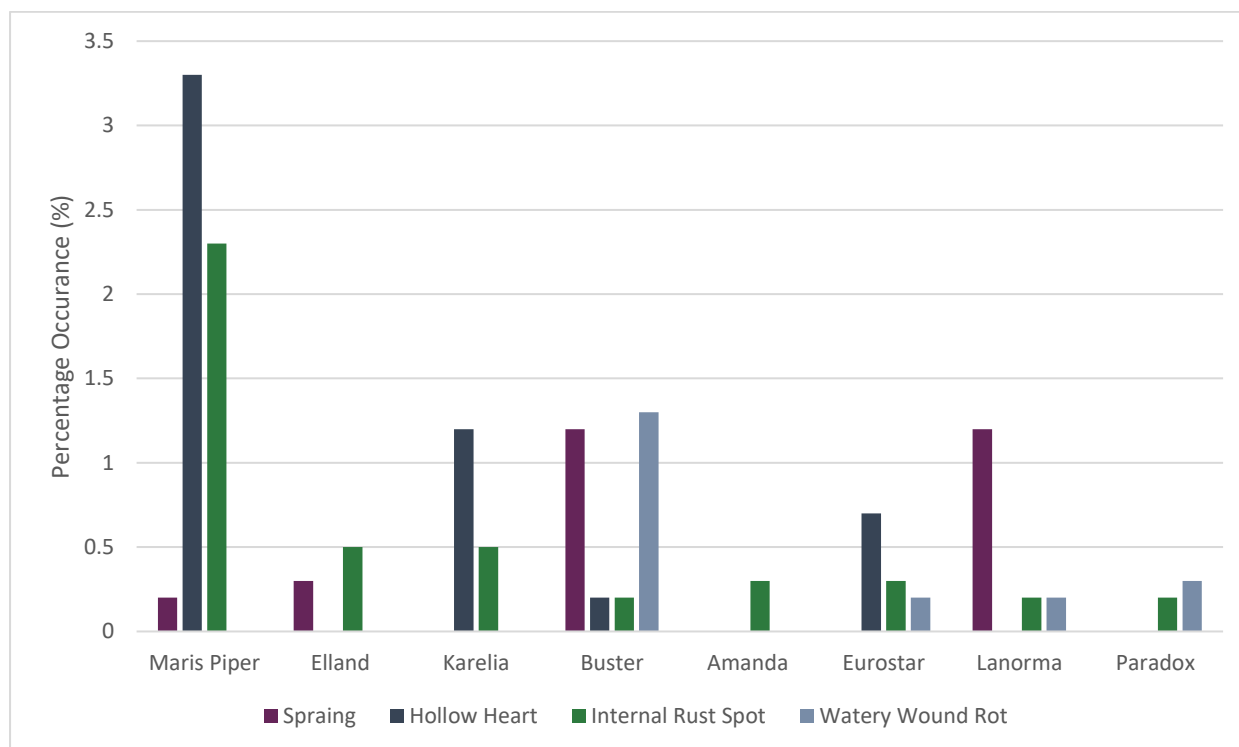


Figure 2 – Percentage occurrence of internal defects by variety in 50 tuber samples (total observed across untreated, Velum Prime, and Nemathorin treated plots).

Initial PCN population (Pi) and PCN population after harvest (Pf)

The initial population (Pi) was determined for each plot and *G. pallida* was the only species detected. Samples to determine Pi were taken on 02/05/23. Variation across the site result in some significant differences between the initial population for the varieties (Table 6). The lowest Pi was recorded in a Karelia plot (5.8eggs/gram) and the highest in a Maris Piper (16.3 eggs/gram) (Figure 3). There was slight significant difference recorded between the treated and untreated plots of certain varieties. The Maris Piper untreated plot started with a Pi of 7 eggs/g which was significantly different to the Pi of 16.3 eggs/g in the Nemathorin treated plot. The Eurostar untreated plot started with a Pi of 7.5 eggs/g which is significantly different to the Pi of 14.0 egg/g in the Velum Prime treated plot. Variation across small areas within a field trial are inevitable but all other Pi counts for the varieties included in this trial were statistically similar.

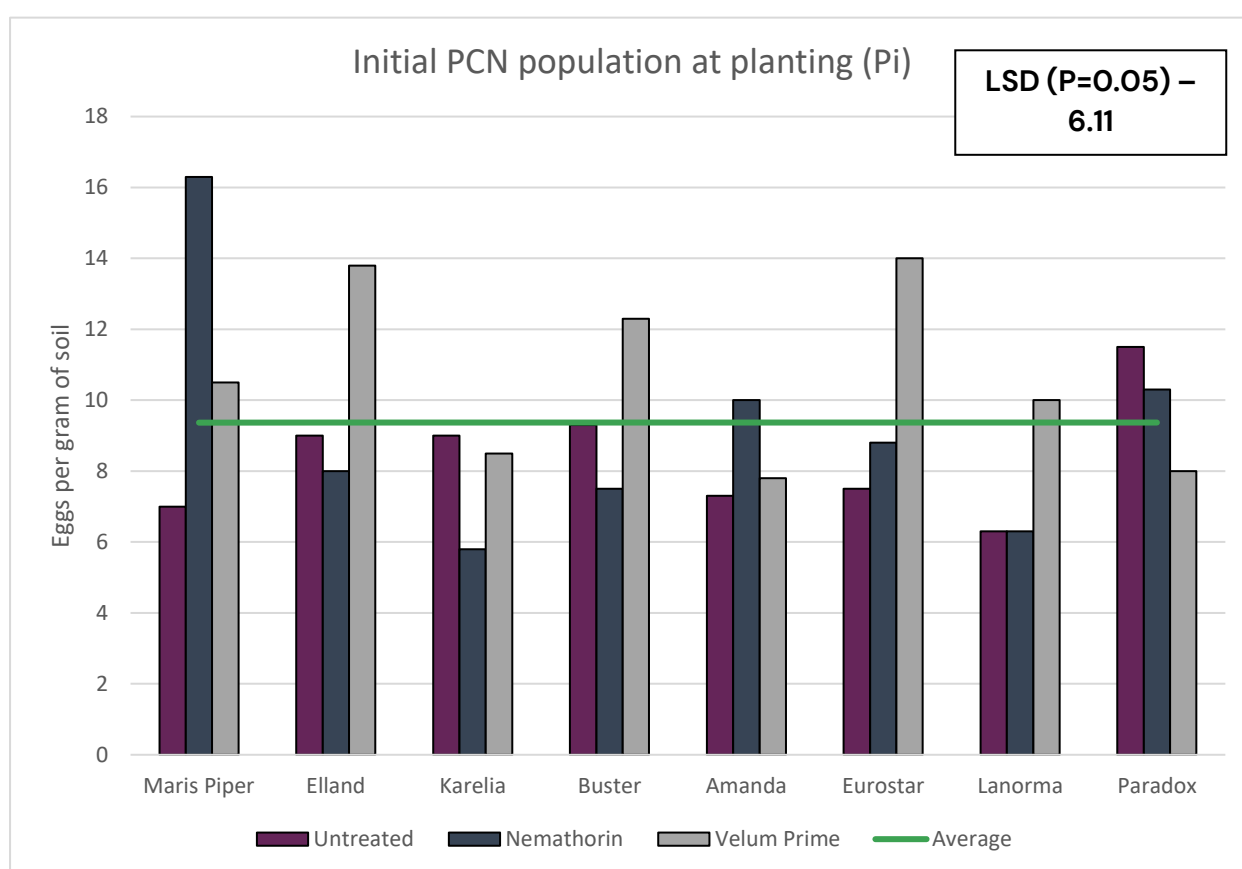


Figure 3 – PCN population (eggs per gram) (Pi) at planting for each variety by treatment. Green bar – Average number of eggs per gram across varieties (9.37 eggs/gram). LSD – Least significant difference.

Table 6 – Analysis of Initial PCN population (Pi) (02/05/2023) and after harvest (Pf) (09/10/2023) expressed as eggs per gram of soil and number of viable cysts.

Variety	Viable Cysts		Eggs/Larvae	Viable Cysts		Eggs/Larvae	Viable Cysts	Eggs/Larvae
	Pi			Pf			Pf/Pi	
	N°/400g	N°/g	N°/g	N°/200g	N°/g	N°/g	N°/g	N°/g
Maris Piper	52.6	0.13	11.3	273.5	1.37	318.3	10.40	28.17
Elland	60.8	0.15	10.3	6.2	0.03	4.2	0.20	0.41
Karelia	47.4	0.12	7.8	10.8	0.05	7.3	0.46	0.94
Buster	48.3	0.12	9.7	1.9	0.01	0.8	0.08	0.08
Amanda	50.7	0.13	8.3	4.6	0.02	3.8	0.18	0.46
Eurostar	49.2	0.12	10.1	17.8	0.09	13.1	0.72	1.30
Lanorma	45.3	0.11	7.5	165.1	0.83	156.8	7.28	20.91
Paradox	52.2	0.13	9.9	24.3	0.12	23.0	0.93	2.32
LSD P=.05	18.03	0.05	3.53	26.74	0.13	30.95		
Standard Deviation	22.14	0.06	4.33	32.83	0.16	38.00		
CV	43.58	43.58	46.39	52.10	52.10	57.67		

Treatment	Viable Cysts		Eggs/Larvae	Viable Cysts		Eggs/Larvae	Viable Cysts	Eggs/Larvae
	Pi			Pf			Pf/Pi	
	N°/400g	N°/g	N°/g	N°/200g	N°/g	N°/g	N°/g	N°/g
Untreated	44.8	0.11	8.3	66.7	0.33	73.2	2.98	8.82
Velum Prime	56.2	0.14	10.6	69.6	0.35	68.8	2.48	6.49
Nemathorin	51.4	0.13	9.1	52.7	0.26	55.7	2.05	6.12
LSD P=.05	11.04	0.03	2.16	16.37	0.08	18.95		
Standard Deviation	22.14	0.06	4.33	32.83	0.16	38.00		
CV	43.58	43.58	46.39	52.10	52.10	57.67		

Variety & Treatment	Viable Cysts		Eggs/Larvae	Viable Cysts		Eggs/Larvae	Viable Cysts	Eggs/Larvae
	Pi			Pf			Pf/Pi	
	N ^o /400g	N ^o /g	N ^o /g	N ^o /200g	N ^o /g	N ^o /g	N ^o /g	N ^o /g
Maris Piper Untreated	37.3	0.09	7.0	316.0	1.58	383.3	16.97	54.76
Maris Piper Velum Prime	49.3	0.12	10.5	264.0	1.32	291.3	10.72	27.74
Maris Piper Nemathorin	71.3	0.18	16.3	240.5	1.20	280.3	6.75	17.20
Elland Untreated	53.8	0.13	9.0	7.5	0.04	3.3	0.28	0.37
Elland Velum Prime	72.5	0.18	13.8	5.3	0.03	4.0	0.15	0.29
Elland Nemathorin	56.0	0.14	8.0	5.8	0.03	5.3	0.21	0.66
Karelia Untreated	44.0	0.11	9.0	10.3	0.05	6.5	0.47	0.72
Karelia Velum Prime	52.5	0.13	8.5	13.3	0.07	9.5	0.51	1.12
Karelia Nemathorin	45.8	0.11	5.8	9.0	0.05	6.0	0.39	1.03
Buster Untreated	35.0	0.09	9.3	1.8	0.01	0.8	0.10	0.09
Buster Velum Prime	67.0	0.17	12.3	3.0	0.02	1.5	0.09	0.12
Buster Nemathorin	42.8	0.11	7.5	1.0	0.01	0.3	0.05	0.04
Amanda Untreated	41.8	0.10	7.3	7.3	0.04	6.3	0.35	0.86
Amanda Velum Prime	59.3	0.15	7.8	5.5	0.03	4.5	0.19	0.58
Amanda Nemathorin	51.0	0.13	10.0	1.0	0.01	0.5	0.04	0.05
Eurostar Untreated	42.3	0.11	7.5	14.5	0.07	13.8	0.69	1.84
Eurostar Velum Prime	61.5	0.15	14.0	22.8	0.11	17.8	0.74	1.27
Eurostar Nemathorin	43.8	0.11	8.8	16.0	0.08	7.8	0.73	0.89
Lanorma Untreated	41.3	0.10	6.3	154.0	0.77	150.3	7.47	23.86
Lanorma Velum Prime	53.0	0.13	10.0	213.5	1.07	190.8	8.06	19.08
Lanorma Nemathorin	41.8	0.10	6.3	127.8	0.64	129.3	6.12	20.52
Paradox Untreated	63.3	0.16	11.5	22.3	0.11	21.5	0.70	1.87
Paradox Velum Prime	34.3	0.09	8.0	29.8	0.15	31.3	1.74	3.91
Paradox Nemathorin	59.0	0.15	10.3	20.8	0.10	16.3	0.70	1.58
LSD P=.05	31.23	0.08	6.11	46.31	0.23	53.60		
Standard Deviation	22.14	0.06	4.33	32.83	0.16	38.00		
CV	43.58	43.58	46.39	52.10	52.10	57.67		

Note 1 – Results with statistical significance for variety between treatments are highlighted in bold.

The population detected after growing (post-harvest sample – Pf) can be analysed as a standalone dataset or interpreted as a ratio between the initial population and the population after harvest (the Pi/Pf ratio) (Table 6). There was no significant effect of Nemathorin or Velum Prime on the Pf values overall for different individual varieties except for Maris Piper and Lanorma (Figure 4). For Maris Piper there was a significant decrease in Pf for both treated plots compared to the untreated. There was no significant difference between the untreated and untreated plots for Lanorma however, there was a significant difference between the Velum Prime and Nemathorin treatment (Pf of 190.8 and 129.3 respectively – LSD of 53.6).

Maris Piper being the susceptible control variety unsurprisingly increased the PCN population from 7 to 383.3 eggs/g, giving a Pf/Pi ratio of 54.76 for the untreated plots. The highly resistant varieties Elland (9), Buster (9), and Amanda (8) all gave Pf/Pi ratios of under 1 (0.66, 0.04, and 0.05 respectively) when treated with Nemathorin and (0.29, 0.12, and 0.58 respectively) Velum Prime. There is then a small jump up to Karelia, Eurostar, and Paradox with Pf/Pi ratios of 1.03, 0.89 and 1.58 when treated with Nemathorin and 1.12, 1.27, and 3.9 with Velum Prime. Lanorma gave a Pf/Pi ratio of 23.9 when untreated, 20.5 with Nemathorin and

19.08 with Velum Prime. This is a significant increase between Lanorma's resistance score of 5 and the highly resistant varieties with scores of 9 and 8 listed above. This demonstrates that partially resistant varieties allow the PCN population in-field to increase but at slower rates than susceptible varieties. The Pf/Pi ratios of the untreated plots show the power of the resistant varieties themselves in reducing PCN populations (Figure 4).

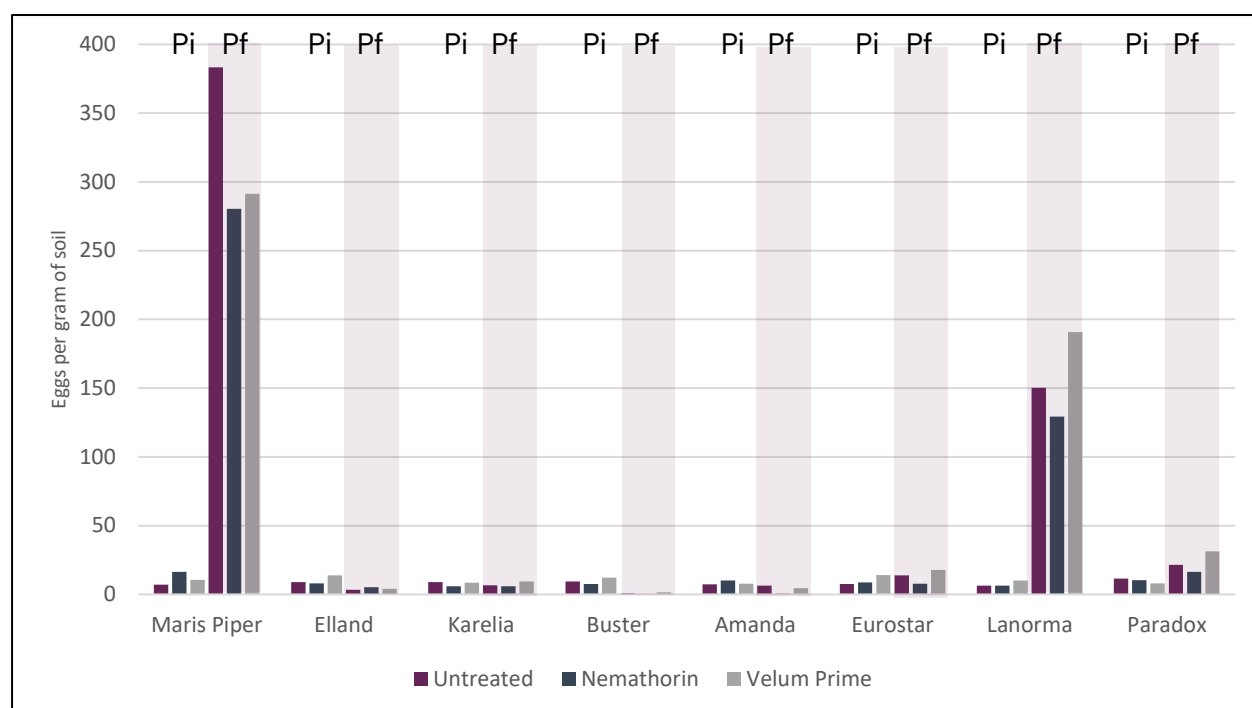


Figure 4 – Pre-plant (Pi) versus Post-harvest (Pf – highlighted in transparent purple boxes) PCN levels (eggs per gram of soil) for varieties treated with Nemathorin, Velum Prime, or untreated replicates.

Yield and tuber numbers

Tables 7 and 8 give the total yield (tonnes per ha) and yield in 5 mm size fractions. The total yield data is summarised in Figure 5. The variety maturity characteristics differ, and this has affected the yield potential. With a longer growing season and appropriate fertiliser applications the yield of later maturing varieties could have been expected to increase.

Differences between the yield of untreated and treated plots provides a measure of the tolerance to PCN (Figure 5). If a variety produces a similar yield across both treated and untreated plots it would be considered tolerant. Maris Piper, Elland, Karelia, and Buster all had yield increases in the treated plots compared to untreated. Although the trend was increased yield for those mentioned there was only a statistically significant increase between the following: Elland untreated and Nemathorin, Karelia untreated and Nemathorin, and Buster untreated and Nemathorin. The yield of Amanda and Eurostar was constant between both treatments and untreated plots with only 0.8 tonnes per hectare between the varieties. The yield for Lanorma and Paradox were more variable. For Lanorma there was no significant difference between untreated (35.22 T/ha) and treated plots, however there was a significant difference between treatments with Velum Prime giving 30.67 T/ha while Nemathorin treatment gave 42.41 T/ha. Paradox gave a higher yield in Velum Prime treated plots (44.47 T/ha) when compared to Nemathorin treatment (37.16 T/ha) and untreated plots (38.6 T/ha) however these differences were not statistically significant.

Table 7 – Total yield (in tonnes per ha) and yield in size fractions between 25mm and 60mm

Variety	Yield Total T/Ha	Yield <25mm T/Ha	Yield 25-30mm T/Ha	Yield 30-35mm T/Ha	Yield 35-40mm T/Ha	Yield 40-45mm T/Ha	Yield 45-50mm T/Ha	Yield 50-55mm T/Ha	Yield 55-60mm T/Ha
Maris Piper	41.55	0.01	0.09	0.26	0.50	1.46	2.64	5.43	8.83
Elland	36.09	0.04	0.16	0.37	0.93	2.41	5.18	7.35	7.57
Karelia	38.16	0.02	0.06	0.28	0.44	1.02	2.57	4.25	8.10
Buster	42.97	0.02	0.10	0.26	0.55	1.00	1.93	3.24	5.61
Amanda	40.27	0.02	0.16	0.31	1.08	2.54	6.01	7.64	9.50
Eurostar	36.59	0.03	0.04	0.17	0.31	0.84	1.80	3.00	6.67
Lanorma	36.10	0.05	0.11	0.47	1.10	2.04	3.52	5.39	5.11
Paradox	40.08	0.02	0.11	0.21	0.46	0.91	2.19	3.71	5.58
LSD P=.05	5.51	0.03	0.07	0.18	0.29	0.53	0.87	1.40	2.14
Standard Deviation	6.76	0.03	0.08	0.22	0.35	0.65	1.06	1.72	2.63
CV	17.35	123.48	78.77	75.95	52.86	42.62	32.94	34.32	36.93

Treatment	Yield Total T/Ha	Yield <25mm T/Ha	Yield 25-30mm T/Ha	Yield 30-35mm T/Ha	Yield 35-40mm T/Ha	Yield 40-45mm T/Ha	Yield 45-50mm T/Ha	Yield 50-55mm T/Ha	Yield 55-60mm T/Ha
Untreated	35.73	0.03	0.11	0.34	0.64	1.67	3.30	5.14	7.02
Velum Prime	38.81	0.03	0.09	0.24	0.75	1.62	3.54	5.54	7.49
Nemathorin	42.38	0.02	0.11	0.29	0.62	1.29	2.85	4.33	6.85
LSD P=.05	3.37	0.02	0.04	0.11	0.18	0.32	0.53	0.86	1.31
Standard Deviation	6.76	0.03	0.08	0.22	0.35	0.65	1.06	1.72	2.63
CV	17.35	123.48	78.77	75.95	52.86	42.62	32.94	34.32	36.93

Variety & Treatment	Yield Total T/Ha	Yield <25mm T/Ha	Yield 25-30mm T/Ha	Yield 30-35mm T/Ha	Yield 35-40mm T/Ha	Yield 40-45mm T/Ha	Yield 45-50mm T/Ha	Yield 50-55mm T/Ha	Yield 55-60mm T/Ha
Maris Piper Untreated	35.02	0.01	0.11	0.29	0.36	1.41	2.92	5.05	7.48
Maris Piper Velum Prime	44.76	0.02	0.09	0.29	0.65	1.42	2.79	5.15	9.10
Maris Piper Nemathorin	44.87	0.01	0.08	0.19	0.48	1.54	2.22	6.10	9.93
Elland Untreated	30.63	0.03	0.14	0.40	0.70	2.93	4.61	6.19	7.99
Elland Velum Prime	37.43	0.06	0.09	0.27	1.22	2.55	6.41	9.36	8.42
Elland Nemathorin	40.22	0.02	0.24	0.45	0.86	1.76	4.53	6.50	6.29
Karelia Untreated	31.04	0.04	0.06	0.44	0.42	1.38	3.40	3.59	7.44
Karelia Velum Prime	37.85	0.01	0.08	0.10	0.24	0.97	2.54	5.88	9.02
Karelia Nemathorin	45.59	0.01	0.04	0.30	0.66	0.70	1.76	3.28	7.85
Buster Untreated	37.50	0.01	0.08	0.24	0.76	0.96	1.88	4.12	5.44
Buster Velum Prime	40.97	0.02	0.11	0.33	0.39	1.00	2.42	3.52	8.14
Buster Nemathorin	50.43	0.04	0.13	0.21	0.50	1.04	1.48	2.08	3.24
Amanda Untreated	40.78	0.03	0.18	0.30	0.99	2.91	6.47	8.02	9.70
Amanda Velum Prime	39.98	0.02	0.09	0.21	1.21	2.71	6.18	8.04	9.70
Amanda Nemathorin	40.04	0.01	0.21	0.41	1.05	2.00	5.37	6.87	9.10
Eurostar Untreated	37.03	0.04	0.05	0.28	0.17	0.83	1.34	2.77	6.05
Eurostar Velum Prime	34.40	0.02	0.04	0.09	0.38	0.81	2.63	4.41	6.29
Eurostar Nemathorin	38.34	0.01	0.03	0.14	0.38	0.88	1.45	1.83	7.69
Lanorma Untreated	35.22	0.07	0.10	0.40	1.09	1.87	2.90	6.21	5.75
Lanorma Velum Prime	30.67	0.05	0.10	0.56	1.44	2.41	3.72	5.02	4.20
Lanorma Nemathorin	42.41	0.05	0.12	0.45	0.77	1.84	3.94	4.93	5.38
Paradox Untreated	38.60	0.04	0.13	0.38	0.68	1.06	2.87	5.15	6.35
Paradox Velum Prime	44.47	0.03	0.16	0.08	0.48	1.07	1.66	2.95	5.05
Paradox Nemathorin	37.16	0.00	0.05	0.17	0.23	0.59	2.04	3.04	5.34
LSD P=.05	9.54	0.04	0.11	0.31	0.50	0.92	1.50	2.42	3.71
Standard Deviation	6.76	0.03	0.08	0.22	0.35	0.65	1.06	1.72	2.63
CV	17.35	123.48	78.77	75.95	52.86	42.62	32.94	34.32	36.93

Table 8 –Yield (tonnes per ha) in marketable fraction (45–65mm and 65–85mm) and in size fractions from 60mm to >85mm

Variety	Yield 60-65mm T/Ha	Yield 65-70mm T/Ha	Yield 70-75mm T/Ha	Yield 75-80mm T/Ha	Yield 80-85mm T/Ha	Yield >85mm T/Ha	Yield 45-65mm T/Ha	Yield >65mm T/Ha
Maris Piper	6.90	7.39	5.13	1.93	0.97	0	23.81	15.42
Elland	6.67	3.12	1.60	0.60	0.11	0	26.76	5.43
Karelia	8.84	5.52	3.16	2.47	0.78	0.65	23.76	12.59
Buster	5.21	8.79	8.04	5.33	1.76	1.14	15.98	25.05
Amanda	7.34	4.34	0.89	0.45	0	0	30.49	5.68
Eurostar	7.96	7.49	4.67	1.87	1.10	0.64	19.44	15.76
Lanorma	5.24	5.60	3.19	1.68	1.56	1.04	19.26	13.07
Paradox	8.21	8.47	6.27	1.55	1.74	0.65	19.69	18.68
LSD P=.05	2.53	2.27	2.34	1.83	1.14	0.99	3.67	5.51
Standard Deviation	3.11	2.78	2.87	2.25	1.40	1.21	4.50	6.76
CV	44.10	43.92	69.64	113.12	139.90	235.30	20.10	48.41

Treatment	Yield 60-65mm T/Ha	Yield 65-70mm T/Ha	Yield 70-75mm T/Ha	Yield 75-80mm T/Ha	Yield 80-85mm T/Ha	Yield >85mm T/Ha	Yield 45-65mm T/Ha	Yield >65mm T/Ha
Untreated	6.10	5.50	3.53	1.19	0.92	0.23	21.56	11.38
Velum Prime	7.21	5.33	3.52	2.12	0.84	0.50	23.78	12.31
Nemathorin	7.83	8.19	5.30	2.65	1.24	0.82	21.86	18.20
LSD P=.05	1.55	1.39	1.43	1.12	0.70	0.60	2.25	3.37
Standard Deviation	3.11	2.78	2.87	2.25	1.40	1.21	4.50	6.76
CV	44.10	43.92	69.64	113.12	139.90	235.30	20.10	48.41

Variety & Treatment	Yield 60-65mm T/Ha	Yield 65-70mm T/Ha	Yield 70-75mm T/Ha	Yield 75-80mm T/Ha	Yield 80-85mm T/Ha	Yield >85mm T/Ha	Yield 45-65mm T/Ha	Yield >65mm T/Ha
Maris Piper Untreated	4.94	5.69	3.65	1.80	1.32	0	20.38	12.46
Maris Piper Velum Prime	7.24	7.43	6.46	3.00	1.14	0	24.28	18.02
Maris Piper Nemathorin	8.53	9.05	5.29	0.99	0.46	0	26.78	15.79
Elland Untreated	5.08	1.68	0.50	0.39	0	0	23.86	2.57
Elland Velum Prime	6.33	2.42	0.00	0.31	0	0	30.52	2.73
Elland Nemathorin	8.59	5.26	4.30	1.10	0.34	0	25.91	10.98
Karelia Untreated	7.44	2.63	2.48	1.35	0.38	0	21.87	6.84
Karelia Velum Prime	9.30	5.00	2.50	1.78	0	0.45	26.73	9.73
Karelia Nemathorin	9.78	8.92	4.51	4.29	1.96	1.52	22.68	21.20
Buster Untreated	4.45	8.40	6.79	3.57	0.81	0	15.88	19.57
Buster Velum Prime	5.84	5.70	6.09	5.06	0.50	1.86	19.92	19.21
Buster Nemathorin	5.35	12.27	11.24	7.37	3.96	1.55	12.14	36.38
Amanda Untreated	7.11	3.46	1.27	0.35	0	0	31.31	5.08
Amanda Velum Prime	7.23	3.14	1.10	0.37	0	0	31.14	4.60
Amanda Nemathorin	7.68	6.43	0.30	0.62	0	0	29.02	7.35
Eurostar Untreated	6.83	8.91	6.31	0.65	2.36	0.46	16.98	18.69
Eurostar Velum Prime	7.32	6.55	2.22	3.27	0.39	0	20.64	12.42
Eurostar Nemathorin	9.74	7.01	5.48	1.70	0.55	1.46	20.70	16.19
Lanorma Untreated	4.95	6.28	3.55	0.28	1.32	0.45	19.81	11.88
Lanorma Velum Prime	5.34	2.78	1.38	1.00	2.04	0.65	18.28	7.84
Lanorma Nemathorin	5.45	7.75	4.64	3.76	1.32	2.01	19.69	19.49
Paradox Untreated	8.04	6.93	3.73	1.12	1.20	0.93	22.40	13.91
Paradox Velum Prime	9.07	9.62	8.43	2.18	2.67	1.03	18.73	23.93
Paradox Nemathorin	7.53	8.85	6.64	1.36	1.34	0	17.95	18.18
LSD P=.05	4.38	3.93	4.05	3.17	1.98	1.71	6.35	9.53
Standard Deviation	3.11	2.78	2.87	2.25	1.40	1.21	4.50	6.76
CV	44.10	43.92	69.64	113.12	139.90	235.30	20.10	48.41

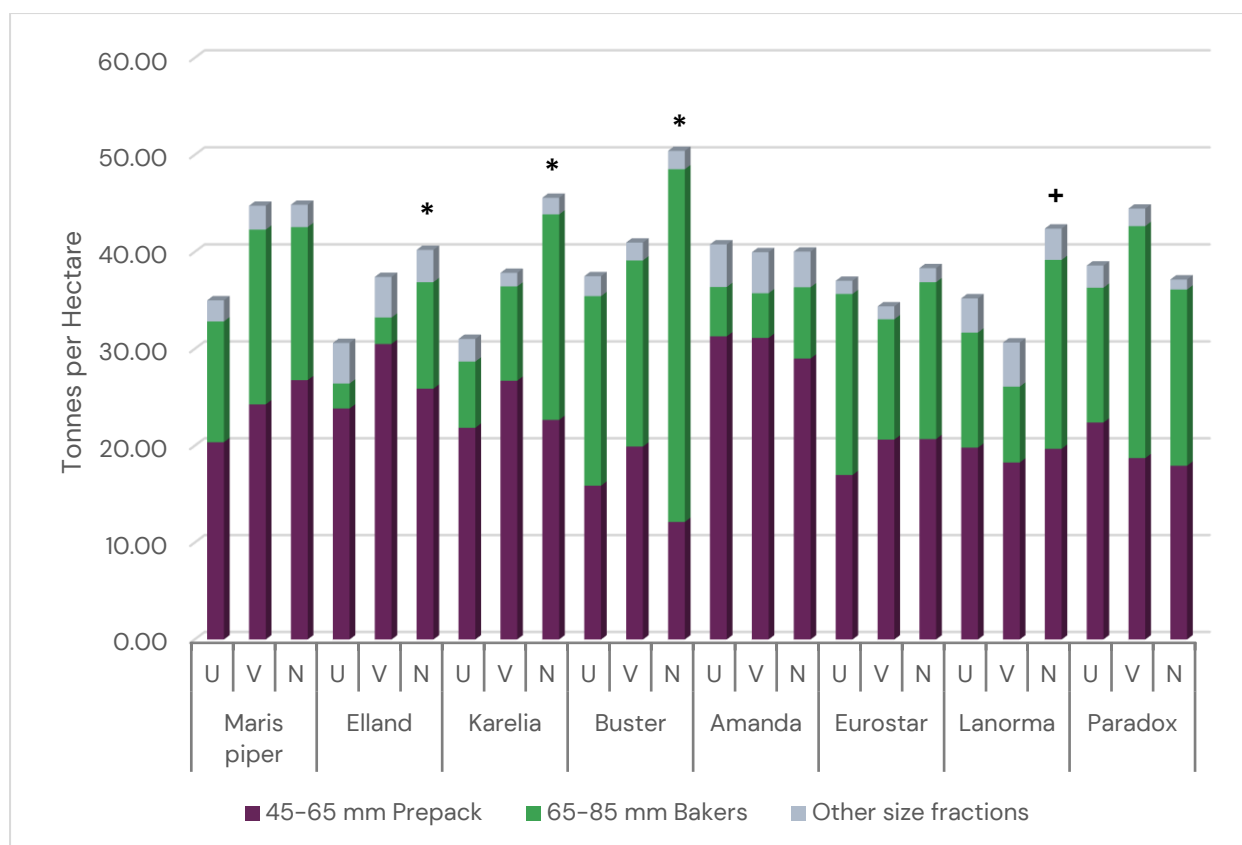


Figure 5 – Total yield (tonnes per ha) of untreated (U), Velum Prime (V), and Nemathorin (N) treatments for each variety. Varieties with a significant difference in total yield between a treatment and the untreated control is indicated by an asterisk. A significant difference between treatments (Velum Prime & Nemathorin) is indicated with a +.

Table 9 – Total tuber numbers (per ha) and number in size fractions between 25mm and 60mm

Variety	Number Total N°/Ha	Number <25mm N°/Ha	Number 25-30mm N°/Ha	Number 30-35mm N°/Ha	Number 35-40mm N°/Ha	Number 40-45mm N°/Ha	Number 45-50mm N°/Ha	Number 50-55mm N°/Ha	Number 55-60mm N°/Ha
Maris Piper	266667	1646	5967	9877	11728	23972	31482	44959	54424
Elland	303704	5247	9568	13580	21914	38272	57099	60185	46914
Karelia	264198	2469	4012	11420	11420	17593	33025	37963	55247
Buster	225926	3086	6790	9568	12963	16667	20679	26543	32716
Amanda	349074	2161	9877	10802	25309	41049	70988	65741	62346
Eurostar	206790	3395	2469	6482	7407	13889	20371	24691	41358
Lanorma	287037	7099	7099	18827	28395	34568	41358	46296	33333
Paradox	242284	2161	6790	8025	11111	15124	25617	32408	36729
LSD P=.05	30924	3376	4266	6592	7003	8767	9864	11788	13416
Standard Deviation	37960	4144	5236	8092	8596	10762	12108	14469	16469
CV	14	122	80	73	53	43	32	34	36

Treatment	Number Total N°/Ha	Number <25mm N°/Ha	Number 25-30mm N°/Ha	Number 30-35mm N°/Ha	Number 35-40mm N°/Ha	Number 40-45mm N°/Ha	Number 45-50mm N°/Ha	Number 50-55mm N°/Ha	Number 55-60mm N°/Ha
Untreated	265625	4051	6945	13195	15972	28241	39005	44213	44907
Velum Prime	272917	3704	6019	9028	18056	26273	40741	46296	47801
Nemathorin	266088	2469	6752	10996	14815	20911	32986	36536	43441
LSD P=.05	18937	2067	2612	4037	4288	5369	6040	7218	8216
Standard Deviation	37960	4144	5236	8092	8596	10762	12108	14469	16469
CV	14	122	80	73	53	43	32	34	36

Variety & Treatment	Number Total N°/Ha	Number <25mm N°/Ha	Number 25-30mm N°/Ha	Number 30-35mm N°/Ha	Number 35-40mm N°/Ha	Number 40-45mm N°/Ha	Number 45-50mm N°/Ha	Number 50-55mm N°/Ha	Number 55-60mm N°/Ha
Maris Piper Untreated	239815	926	7407	11111	8333	24074	35185	42593	46296
Maris Piper Velum Prime	282408	2778	5556	11111	15741	23149	33334	41667	56482
Maris Piper Nemathorin	277778	1235	4938	7408	11111	24692	25926	50617	60494
Elland Untreated	273148	4630	9259	14815	16667	46297	50000	49074	49074
Elland Velum Prime	336111	7407	5556	9259	28704	40741	72222	78704	52778
Elland Nemathorin	301852	3704	13889	16667	20371	27778	49074	52778	38889
Karelia Untreated	255556	5556	3704	18519	11111	25000	43519	33333	50000
Karelia Velum Prime	262037	926	5556	3704	6482	15741	32408	50926	61111
Karelia Nemathorin	275000	926	2778	12037	16667	12037	23148	29630	54630
Buster Untreated	218519	1852	5556	9260	18519	16667	20371	34260	31482
Buster Velum Prime	225000	2778	6482	12037	9259	16667	24074	27778	47222
Buster Nemathorin	234259	4630	8334	7408	11111	16667	17593	17593	19445
Amanda Untreated	367593	3704	11111	10185	24074	47222	76852	71296	64815
Amanda Velum Prime	349074	1852	6482	7407	27778	44444	74074	67593	63889
Amanda Nemathorin	330556	926	12037	14815	24074	31481	62037	58334	58333
Eurostar Untreated	205556	4630	2778	10185	3704	13889	15741	22222	38889
Eurostar Velum Prime	210185	3704	2778	3704	9259	12963	28704	37037	39815
Eurostar Nemathorin	204630	1852	1852	5556	9259	14815	16667	14815	45371
Lanorma Untreated	292593	7407	7408	16667	29630	34259	36111	55556	37037
Lanorma Velum Prime	274074	7407	6482	22223	36111	38889	42593	41667	27778
Lanorma Nemathorin	294444	6482	7408	17593	19445	30556	45371	41667	35185
Paradox Untreated	272222	3704	8334	14815	15741	18519	34259	45371	41667
Paradox Velum Prime	244444	2778	9260	2778	11111	17593	18519	25000	33334
Paradox Nemathorin	210185	0	2778	6482	6482	9259	24074	26852	35185
LSD P=.05	53562	5847	7388	11419	12129	15185	17085	20417	23237
Standard Deviation	37960	4144	5236	8092	8596	10762	12108	14469	16469
CV	14	122	80	73	53	43	32	34	36

Table 10 – Tuber number (per ha) in marketable fractions (45–65mm and 65–85mm) and in size fractions from 60mm to >85mm

Variety	Number 60-65mm Nº/Ha	Number 65-70mm Nº/Ha	Number 70-75mm Nº/Ha	Number 75-80mm Nº/Ha	Number 80-85mm Nº/Ha	Number >85mm Nº/Ha	Number 45-65mm Nº/Ha	Number >65mm Nº/Ha
Maris Piper	33333	27058	15124	4835	2263	0	164198	49280
Elland	31790	12037	5247	1543	309	0	195988	19136
Karelia	47222	23148	10802	6790	1852	1235	173457	43827
Buster	23457	32099	23457	12654	3395	1852	103395	73457
Amanda	38580	17901	3086	1235	0	0	237654	22222
Eurostar	37654	27778	13889	4321	2161	926	124074	49074
Lanorma	26852	22531	10803	4630	3395	1852	147840	43210
Paradox	41975	33642	19753	4012	3704	1235	136728	62346
LSD P=.05	13154	9153	7215	4398	2471	1665	24646	16491
Standard Deviation	16146	11235	8857	5399	3034	2044	30253	20243
CV	46	46	69	108	142	230	19	45

Treatment	Number 60-65mm Nº/Ha	Number 65-70mm Nº/Ha	Number 70-75mm Nº/Ha	Number 75-80mm Nº/Ha	Number 80-85mm Nº/Ha	Number >85mm Nº/Ha	Number 45-65mm Nº/Ha	Number >65mm Nº/Ha
Untreated	31019	21412	11227	3009	1968	463	159144	38079
Velum Prime	35764	20602	10764	5208	1852	810	170602	39236
Nemathorin	38542	31559	16320	6790	2585	1389	151505	58642
LSD P=.05	8055	5605	4419	2693	1513	1020	15092	10099
Standard Deviation	16146	11235	8857	5399	3034	2044	30253	20243
CV	46	46	69	108	142	230	19	45

Variety & Treatment	Number 60-65mm Nº/Ha	Number 65-70mm Nº/Ha	Number 70-75mm Nº/Ha	Number 75-80mm Nº/Ha	Number 80-85mm Nº/Ha	Number >85mm Nº/Ha	Number 45-65mm Nº/Ha	Number >65mm Nº/Ha
Maris Piper Untreated	24074	21296	11111	4630	2778	0	148148	39815
Maris Piper Velum Prime	35185	27778	19445	7407	2778	0	166667	57407
Maris Piper Nemathorin	40741	32099	14815	2469	1235	0	177778	50617
Elland Untreated	24074	6482	1852	926	0	0	172222	9259
Elland Velum Prime	30556	9259	0	926	0	0	234259	10185
Elland Nemathorin	40741	20371	13889	2778	926	0	181482	37963
Karelia Untreated	39815	11111	9259	3704	926	0	166667	25000
Karelia Velum Prime	50000	21297	7408	5556	0	926	194444	35186
Karelia Nemathorin	51852	37037	15741	11111	4630	2778	159259	71296
Buster Untreated	20371	30556	19444	8334	1852	0	106482	60185
Buster Velum Prime	25926	20371	17593	11111	926	2778	125000	52778
Buster Nemathorin	24074	45370	33333	18519	7407	2778	78704	107408
Amanda Untreated	37963	14815	4630	926	0	0	250926	20371
Amanda Velum Prime	37963	12963	3704	926	0	0	243519	17593
Amanda Nemathorin	39815	25926	926	1852	0	0	218519	28704
Eurostar Untreated	33334	33334	19444	1852	4630	926	110185	60185
Eurostar Velum Prime	33334	24074	6482	7408	926	0	138889	38889
Eurostar Nemathorin	46296	25926	15741	3704	926	1852	123148	48148
Lanorma Untreated	25926	25926	12037	926	2778	926	154630	42593
Lanorma Velum Prime	26852	11111	4630	2778	4630	926	138889	24074
Lanorma Nemathorin	27778	30556	15741	10185	2778	3704	150000	62963
Paradox Untreated	42592	27778	12037	2778	2778	1852	163889	47222
Paradox Velum Prime	46297	37963	26852	5556	5555	1852	123148	77778
Paradox Nemathorin	37037	35185	20371	3704	2778	0	123148	62037
LSD P=.05	22783	15853	12498	7617	4281	2885	42688	28564
Standard Deviation	16146	11235	8857	5399	3034	2044	30253	20243
CV	46	46	69	108	142	230	19	45

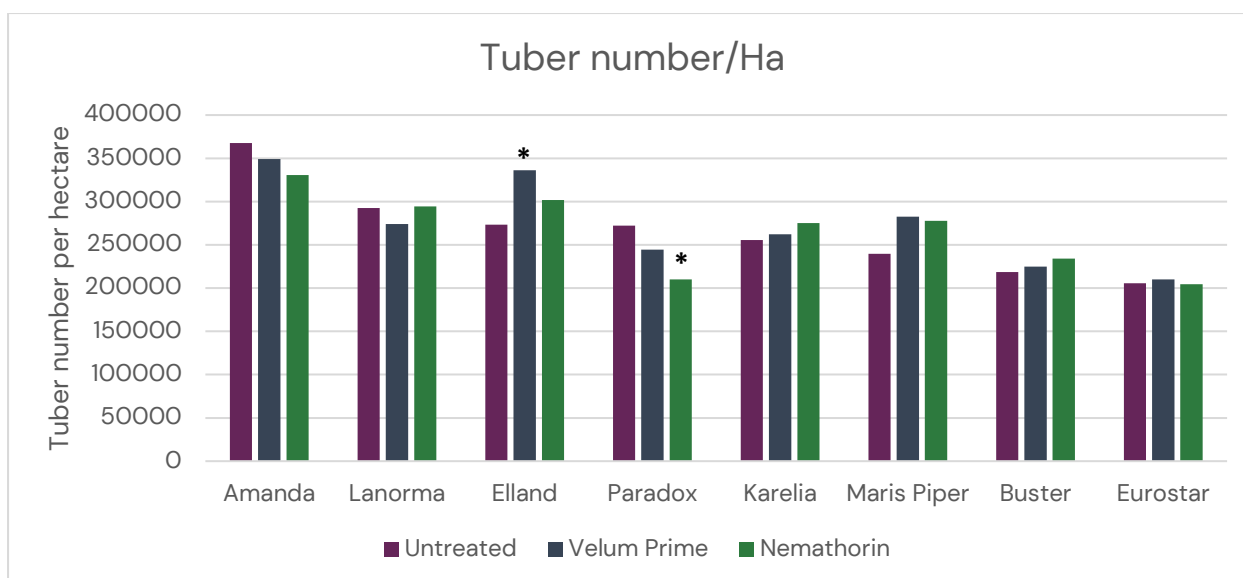


Figure 6 – Total tuber numbers (per ha) for untreated, Velum Prime and Nemathorin treated varieties. Significant difference between treated and untreated within varieties is indicated by an *.

Treatment with either Velum Prime or Nemathorin generally increased tuber numbers for most varieties (Tables 9 & 10) (Maris Piper, Elland, Karelia, and Buster). Only Velum Prime treatment in Elland produced a statistically significant increase in tuber number when compared to the untreated plots (Figure 6). Eurostar remained consistent across all treatments. Lanorma was consistent in tuber numbers between the untreated and Nemathorin plots but showed a reduction in the Velum Prime treated plots. Interestingly Amanda and Paradox showed a reduction in yield in the treated plots with a statistically significant decrease in tuber number when Nemathorin was applied.

From this data we can conclude that Elland is a tolerant variety, but performance can be further enhanced with application of velum Prime. Karelia, Buster, Eurostar, and Lanorma all present as tolerant in this trial. The results from the 2022 barnyards trials also concluded that Elland, Buster, and Karelia are tolerant varieties. The data for Maris Piper suggests that this variety is moderately intolerant to *G. pallida*, however this bucks a trend of data external to this trial stating Maris Piper is moderately tolerant. Differences in tolerance can be affected by external factors such as the weather conditions across the growing season, so this may be an anomaly given 2023 was significantly wetter than average. Nematicide treatment resulted in increased tuber numbers, however the tuber number differences are not statistically different. The same conclusion applies to Amanda although the tuber numbers for this variety decreased in treated plots.

Generally, there was no significant effect of Velum Prime or Nemathorin application on the number of tubers harvested. The differences observed are far more likely to be attributable to varietal differences.

Tuber blemish diseases

While PCN are currently the most significant potato pathogen in the UK, it is important to also consider the resistance/susceptibility status of these varieties to other common blemish diseases (Figure 7). Tubers from the untreated plots were all assessed for common scab, Powdery scab, black scurf (*Rhizoctonia*), silver scurf, and black dot (Table 11). Tubers were also assessed for netting and splits as these symptoms can be caused by multiple blemish diseases. Overall there was a high occurrence of multiple blemish diseases across all varieties at this trial site.

Common scab – The incidence of common scab was variable, ranging between 1% and 37.5%. Three varieties had relatively low incidence (%) and severity – Elland, Karelia, and Lanorma (2.5%, 8%, 1%). Buster and Amanda had a moderate incidence level (11.5% and 15%) while Maris Piper, Eurostar, and Paradox had high incidence levels of common scab (37.5%, 20%, 28.5%). It should be noted that the site was irrigated. However, the regime was uniform across all varieties and the regime not optimised for every variety stage of development.

Powdery scab – Powdery scab was present in all varieties in this year's trial, ranging between 16.5% and 73.5% incidence. Buster, Amanda, and Paradox all had over 50% incidence rates (51.5%, 54%, 57.5%). Both Eurostar and Lanorma had both high incidence and severity rates (73.5% and 72.8% respectively). High incidence of powdery scab is not unexpected as most varieties in this trial have a resistance score of less than 5 (Table 2). The result for Amanda is less expected as it has a score of 7.

Netting & Splits – There was a high incidence of netting across all varieties, ranging from 28.8% to 86.5%. Netting is a symptom that can be caused by multiple blemish diseases such as black scurf and scab. Incidence of splitting was low (between 0 – 2%) and very few were of high severity (zero in severity 3 category).

Black dot – In contrast with the 2022 trial results which had low black dot incidence, there was lots observed in 2023. Varietal incidence ranged between 23.5 – 69.6%. Black dot severity was mixed across varieties with Amanda having the most severe symptoms observed and Buster having the least.

Black scurf – black scurf levels at this trial were low to moderate (4.5 – 35%) and low in severity.

Silver scurf – There were high levels of silver scurf observed but for the most part low in severity. Karelia, Paradox, and Amanda had a slightly elevated number of tubers with a severity score of 2 but nothing outside usual varietal norms.

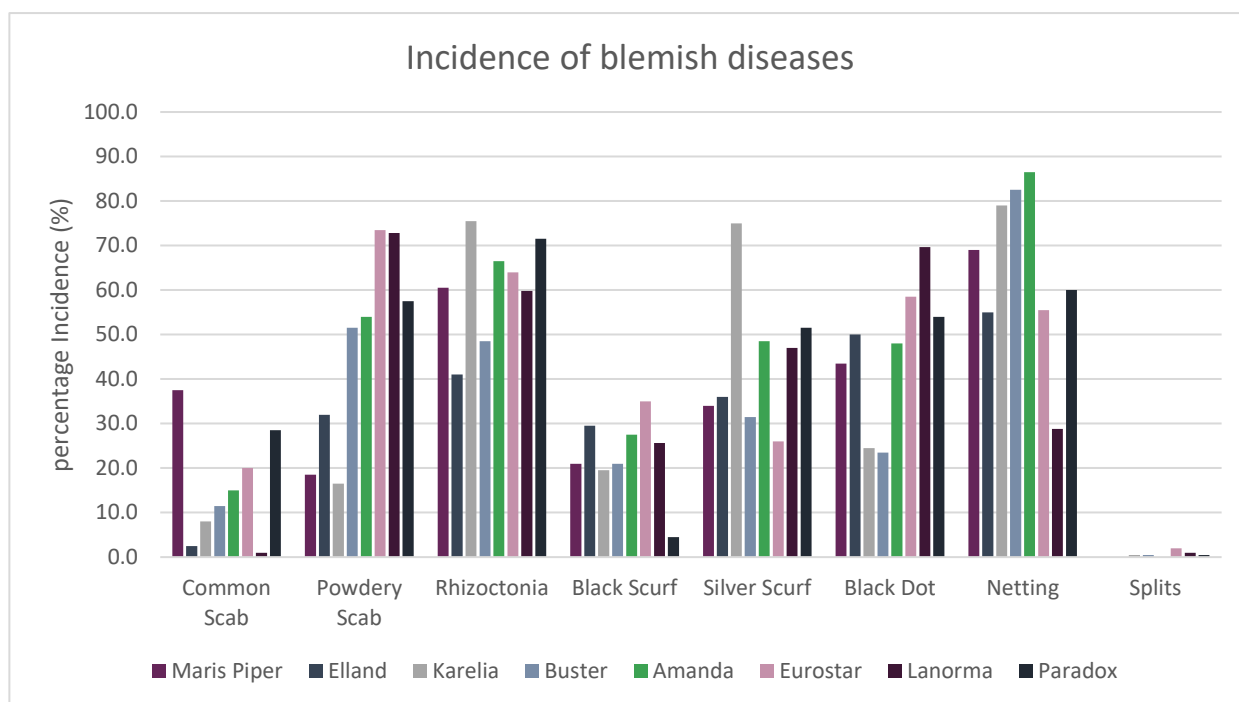


Figure 7 – Percentage incidence of blemish diseases by variety.

Table 11 – *incidence and severity of Common scab (Streptomyces spp.), Powdery scab (Spongospora subterranea), Netting and Splits, Black dot (Colletotrichum coccodes), black scurf (Rhizoctonia solani) and silver scurf (Helminthosporium solani) on harvested tubers*

Varieties	Common Scab						Powdery Scab					
	Incidence %	Severity 0-3	Severity 0	Severity 1	Severity 2	Severity 3	Incidence %	Severity 0-3	Severity 0	Severity 1	Severity 2	Severity 3
Maris Piper	37.5	0.470	62.5	30.0	5.5	2.0	18.5	0.240	81.5	14.5	2.5	1.5
Elland	2.5	0.035	97.5	2.5	0	0	32.0	0.380	68.0	28.0	2.0	2.0
Karelia	8.0	0.085	92.0	7.5	0.5	0	16.5	0.170	83.5	16.0	0.5	0
Buster	11.5	0.115	88.5	11.5	0	0	51.5	0.645	48.5	40.5	9.0	2.0
Amanda	15.0	0.175	85.0	12.5	2.5	0	54.0	0.625	46.0	46.0	7.5	0.5
Eurostar	20.0	0.240	80.0	16.5	3.0	0.5	73.5	1.080	31.5	40.5	16.5	11.5
Lanorma	1.0	0.010	99.0	1.0	0	0	72.8	1.103	27.3	46.3	15.5	11.0
Paradox	28.5	0.355	71.5	23.5	3.0	2.0	57.5	0.745	42.5	44.5	9.0	4.0
LSD P=.05	13.40	0.17	13.40	11.61	3.57	1.89	16.98	0.23	15.87	12.63	6.06	5.49
Standard Deviation	9.12	0.11	9.12	7.90	2.43	1.28	11.55	0.16	10.79	8.59	4.12	3.73
CV	58.81	61.17	10.79	60.16	133.86	228.28	24.55	25.47	20.14	24.88	52.75	91.89

Treatment	Netting	Splits					Black Dot					
	Incidence %	Incidence %	Severity 0-3	Severity 0	Severity 1	Severity 2	Incidence %	Severity 0-3	Severity 0	Severity 1	Severity 2	Severity 3
Maris Piper	69.0	0	0	100.0	0	0	43.5	0.600	56.5	30.5	9.5	3.5
Elland	55.0	0	0	100.0	0	0	50.0	0.610	50.0	40.0	9.0	1.0
Karelia	79.0	0.5	0.010	99.5	0	0.5	24.5	0.280	75.5	21.0	3.5	0
Buster	82.5	0.5	0.005	99.5	0.5	0	23.5	0.255	76.5	21.5	2.0	0
Amanda	86.5	0	0	100.0	0	0	48.0	0.810	52.0	23.5	16.0	8.5
Eurostar	55.5	2.0	0.030	98.0	1.0	1.0	58.5	0.875	41.5	36.0	16.0	6.5
Lanorma	28.8	1.0	0.015	99.0	0.5	0.5	69.6	0.905	30.5	53.3	12.3	4.3
Paradox	60.0	0.5	0.005	99.5	0.5	0	54.0	0.785	46.0	33.5	16.5	4.0
LSD P=.05	18.52	1.25	0.02	1.25	0.71	0.90	18.02	0.30	18.05	14.34	10.30	4.41
Standard Deviation	28.71	221.59	252.84	1.25	227.62	359.89	12.26	0.21	12.27	9.75	7.01	3.00
CV	21.59	432.67	454.31	0.48	600.00	600.00	26.38	32.16	22.91	30.10	66.14	86.41

Varieties	Rhizoctonia	Black Scurf						Silver Scurf					
	Incidence %	Incidence %	Severity 0-3	Severity 0	Severity 1	Severity 2	Severity 3	Incidence %	Severity 0-3	Severity 0	Severity 1	Severity 2	Severity 3
Maris Piper	60.5	21.0	0.215	79.0	20.5	0.5	0	34.0	0.395	66.0	28.5	5.5	0
Elland	41.0	29.5	0.335	70.5	27.0	1.0	1.5	36.0	0.430	64.0	30.5	4.0	1.5
Karelia	75.5	19.5	0.210	80.5	18.0	1.5	0	75.0	0.885	24.5	62.5	13.0	0
Buster	48.5	21.0	0.220	79.0	20.0	1.0	0	31.5	0.320	68.5	31.0	0.5	0
Amanda	66.5	27.5	0.285	72.5	26.5	1.0	0	48.5	0.585	51.5	39.5	8.0	1.0
Eurostar	64.0	35.0	0.365	65.0	33.5	1.5	0	26.0	0.275	74.0	24.5	1.5	0
Lanorma	59.8	25.6	0.293	74.5	22.5	2.8	0.5	47.0	0.545	53.0	40.5	5.5	1.0
Paradox	71.5	4.5	0.045	95.5	4.5	0	0	51.5	0.630	48.5	41.0	9.5	1.0
LSD P=.05	15.20	32.23	0.35	32.25	30.19	2.61	1.16	20.53	0.27	20.20	15.42	7.27	1.42
Standard Deviation	10.34	21.92	0.24	21.93	20.53	1.77	0.79	13.96	0.18	13.73	10.49	4.94	0.97
CV	16.98	95.49	96.69	28.46	95.21	153.22	314.72	31.95	35.72	24.42	28.15	83.21	171.86

Discussion

The results of this trial provide further evidence of the large effect of varieties highly resistant to *G. pallida* can have on the pest population. The varieties Elland, Buster, Amanda, and Karelia resulted in a P_i/P_f ratio of less than 1, actively reducing PCN populations. In contrast the *G. pallida* susceptible, or partially resistant varieties (Maris Piper and Lanorma) resulted in large increases in the pest population at harvest (P_i/P_f ratio of 54.76 and 23.9 respectively in untreated plots). Resistance is a powerful tool in the management of PCN populations and varietal choice should be treated as the most important tool when trying to reduce a PCN problem.

Of these varieties, Elland and paradox have resistance only to *G. pallida* and not to *G. rostochiensis*. However, Eurostar, Buster, and Amanda can be considered resistant to both species of PCN present in Scotland. The effect on a *G. rostochiensis* population was not assessed in this field trial as *G. rostochiensis* was not detectable at this site. Although *G. rostochiensis* is the now the lesser found PCN in Scotland, it should not be forgotten about. Switching to varieties only resistant against *G. pallida* will cause a swing back towards *G. rostochiensis* prevalence. From an integrated pest management (IPM) perspective highly resistant varieties are not necessary if no PCN has been detected. If a field has previously had PCN present but is no longer detectable PCN is likely to be there but just below detectable levels. In this instance resistant varieties should be used however partially resistant varieties can be considered here. A larger detectable PCN population should be combatted using highly resistant varieties specific to the species of PCN present.

The initial average population ($P_i = 9.4$ eggs per gram) can be considered a low-moderate risk field. The P_i for the 2022 trial site was substantially higher at an average of 31.5 eggs per gram of soil, but trends in P_f/P_i for resistant varieties remain constant. It would be interesting to note whether this field has had a higher PCN count historically to assess if the IPM strategies in place at Barnyards Farm are having a positive effect on population numbers over a longer time period outside of PCN Action Scotland's work. The large difference in starting populations between fields in 2022 and 2023 may account for the reduced differences in tolerance that were observed in this year's trial data. Tolerance data varies depending on environmental and seasonal factors impacting variety growth. Therefore it is important to build up multiple years of data before making firm judgements on a varieties tolerance status.

Neither Velum Prime (fluopyram) or Nemathorin (fosthiazate) treatment had an impact on pest multiplication, and this was the case for all varieties. Labels describe that application of these products can protect the crop from the direct effects of feeding damage and a yield enhancement was observed. This set of trial data showed a significant yield increase when Nemathorin was used on Elland, Karelia, and Buster. For these resistant varieties, this difference in yield can provide an important measure of the tolerance of a variety to infection. Other varieties did see some yield increases that were not statistically significant so are much more likely to be down to varietal differences.

Overall there was a high occurrence of multiple blemish diseases across all varieties at this trial site. This could be due to the trial being at a different field site from the 2022 trial. The 2023 field site may have had a higher base level of other diseases present e.g. powdery scab.

This has come out in the data for the year trial however it could be background noise. It is also possible that due to the wetter than average season the tubers were more prone/susceptible to blemish diseases. There is natural variation in the varieties to different blemish diseases which could cause the variation observed e.g. Maris Piper has a resistance score of 1 for Common Scab and had 37.5% incidence in this trial. Application of Nemathorin or Velum Prime was not assessed for effect on the instance of blemish diseases in this trial. Neither product has any effect on blemish diseases reported on label.

A summary of the varieties tested in both the 2022 and 2023 trials can be found in Table 12.

Table 12: Summary of variety performance from 2022 and 2023 trials data

Variety	Resistance to PCN		Comments
	<i>G. pallida</i>	<i>G. rostochiensis</i>	
Cara	2	9	Fully susceptible and tolerant control variety. Low yield due to short season.
Maris Peer	2	2	Fully susceptible and tolerant control variety.
Maris Piper	9	2	Maincrop with high yield and <i>G. rostochiensis</i> resistance. Relatively tolerant.
Elland	9	3	Early maincrop with full resistance to <i>G. pallida</i> . Relatively tolerant. Moderate yield. Suitable for prepacking.
Innovator	8	2	Second early with full resistance to <i>G. pallida</i> . Considered to be intolerant. Widely grown for French fry production. Skin finish is unsuitable for prepacking.
Eurostar	9	9	Maincrop with dual resistance. Shown to be intolerant in this trial. Moderate yield. Suitable for prepacking and general use.
Buster	9	9	Late Maincrop with dual resistance. Emergence delayed. Shown to be intolerant in this trial. High yield. Considered suitable for prepacking.
Amanda	8	R	Medium early with dual resistance. Shown to be intolerant in this trial. High yield. Considered suitable for prepacking.
Karelia	8	8	Medium early with dual resistance. Shown to be relatively tolerant in this trial. High yield. Considered suitable for prepacking.
Cinderella	6	R	Early with partial resistance to <i>G. pallida</i> . Shown to be relatively tolerant in this trial. Lower yield. Considered unsuitable for prepacking due high dry matter content.
Lanorma	5	9	Early maincrop with partial resistance to <i>G. pallida</i> and less suitable than fully resistant varieties in population management. Shown to be relatively tolerant in this trial. High yield. Suitable for prepacking.
Paradox	S	8	High yielding Maincrop with <i>G. pallida</i> resistance. Suitable for French frying and fresh use.
Tyson	4	1	Maincrop with partial resistance to <i>G. pallida</i> and less suitable than fully resistant varieties in population management. Shown to be intolerant in this trial. Moderate yield. Suitable for prepacking.

Acknowledgements

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Appendices

Appendix 1 – percentage ground cover by variety

