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The Effects of Potato Golden Cyst Nematode Pathotype 2/3 On Plant Development in Clones and Varieties

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ABSTRACT

This study investigated the effects of Potato Golden Cyst Nematode (*Globodera rostochiensis*) on plant development and tuber yield in naturally infested fields with and without nematicides. The study was arranged in a randomized block design in the Alay district of Niğde province in 2021. In the study 4 varieties (PAE 13-08-07 clone, Ünlenen, Leventbey, Muratbey) developed by Niğde Potato Research Institute and two controls (Desiree and Bettina) were used. 50% emergence time, 50% flowering time, number of stems per plant, plant height, tuber maturation time, number of large tubers in total tuber and tuber yield per hectare were examined in potato varieties. No difference was detected in 50% emergence time, number of stems per plant and 50% flowering time in potato varieties in the nematicide-applied area and the nematode-infested area. Varieties were affected by nematicide application at varying rates in terms of plant height and tuber maturation time. The most significant increase in tuber size and tuber weight was observed as a result of nematicide application in the field infested with Potato Golden Cyst nematode.

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Introduction

Potato is an industrial plant essential to human nutrition worldwide. After corn , rice, and wheat, potato is the most produced plant (Arvas et al., 2018). Potato is a significant species due to its high nutritional content, suitability for long-term storage, and high productivity (Dumanoğlu & Geren, 2020). They provide high yields per unit area, prevent unbalanced nutrition, and meet the raw material needs in many industrial sectors (Arıoğlu et al., 2006).

Niğde, Afyonkarahisar, and Konya are important provinces in potato production in Turkiye. These provinces constitute almost 35% of the country's output and 32% of the planting areas. The province with the highest production is Niğde, with 679653 tons of production on 17630 hectares of land. The average yield of Niğde is 38.55 t/ha (Tuik, 2022). *Globodera rostochiensis* and *Globodera pallida* are the most important pest in many countries (Tagem, 2017; Subbotin et al., 2020). Important nematode species that cause economic damage in potatoe are Golden Cyst Nematode *Globodera rostochiensis* (Wollenweber) and Pale Cyst Nematode *Globodera pallida* (Taş) Behrens (Turner, 2013). When PCN are not controlled, yield losses of up to 80% occur, causing significant economic losses in the potato industry worldwide (Talavera, 1998; Contina, 2020).

PCN feed on plant roots and disrupt the plant's water and nutrient uptake. Swelling and clustering occur in plant roots. At the beginning of the infection, symptoms of weakening, growth retardation, and wilting begin to appear in the above-ground parts of the plants. Cyst Nematodes, which do not cause significant damage to the upper parts of the plant at the beginning, cause substantial decreases in yield if potato production continues. PCN larvae in the cyst

maintain their viability for many years (10-30 years) even if there is no host plant to feed on in the soil (Gartner et al., 2021). Their eggs can survive for more than twenty years, so it is difficult to destroy them after they emerge (Gartner et al., 2021). In Turkiye, the PCN was first detected in a potato field in the Dörtdivan district of Bolu (Enneli & Öztürk, 1996). In a study conducted in potato growing areas in the Aegean Region, it was determined that the *Globodera rostochiensis* was prevalent in 17.47% of potato production areas in Ödemiş district of İzmir province and 61.70% (Ulutaş, 2010). It was determined that the *G. rostochiensis* was prevalent in 35% of the potato production areas in Bolu province (İmren, 2018). The PCN (*G. rostochiensis)* has also been encountered in the provinces of Niğde, Nevşehir, İzmir and Afyon in Turkiye, and its pathotype was determined as Ro2/3 (Evlice, 2021).

Control of PCN has traditionally been achieved by integrated pest management strategy inculuding crop rotation, cultivation of resistant cultivars and application of nematicides. However, the lack of cultivars with sufficent resistance to *Globedara. pallida* and the limitations associated with long rotations requirement for effective control of those pest support the reliance on chemical control tactices for managing it (Trudgill et al., 2003).

The presence of PCN in potato production areas and above the economic damage limit (Demirbaş Pehlivan, 2019) significantly reduces potato yield. It takes many years for producers to realize that the nematode causes a decrease in tuber yield. The absence of symptoms specific to PCN reduces disease awareness among producers (Price et al., 2021). The effect of increasing global temperatures due to climate change in the last century on loss of productivity caused by plant pests, including soil-dwelling organisms such as PCN, is alarming (Kaczmarek, 2019). From this perspective, provinces where potato cultivation is carried out are at risk in terms of reduced yield. Most of the potato varieties used in the Turkiye are not resistant to PCN, and information on sustainable farming practices is limited. With the increasing costs associated with chemical applications, farmers need to be increasingly efficient in their use of agrochemical resources. In this context, growers need information on correct nematicide application against pathogenic nematodes.

The present study aimed to research the effects of 400 g/l fluopyram nematicide in fields naturally infected with *G. rostochiensis* Ro2/3 race in relation to tuber yield and growth of 6 different potato varieties currently produced in Niğde province.

Materials and Methods

In the study six potato varieties and clone, including PAE 13-08-07, Ünlenen, Leventbey, Muratbey, susceptible control Desiree, and resistant control Bettina were used. The nematode pathotype in the field where the experiment was carried out was determined to be *Globodera rostochiensis* Ro2/3 (Evlice, 2021). The varieties and their characteristics are given in Table 1.

Before the study, a survey was conducted in the town of Alay and soil samples were taken from different locations. Nematode cysts were collected in the samples under a binocular microscope.

Table 1. Characteristics of varieties used in the study

Variety	Maternal × Paternal
Ünlenen	Provento × Soleia
Leventbey	Soleia × Anais
Muratbey	Panda × Anais
PAE 13-08-07	Bettina × Galata
Desiree*	Urgenta × Depesche
Bettina**	Franzi × 795/883

*Susceptible control, **Resistant control (*;**References; ECPD, 2022)

As a result of the evaluation, counts were made in the soil samples taken from the location where the nematode population was dense. Nematode cysts were molecularly and classically identified as Potato Golden Cyst Nematode. The research was conducted in a field naturally infested with nematodes in the Alay district of Niğde province, in accordance with the randomized block design, the experiment was established in 48 plots, including 6 varieties, 4 replicates, and 2 applications. The study consisted of 24 plots naturally infested with Potato Golden Cyst Nematode and 24 plots treated with nematicide. In the experiment, the plot width was determined as 1.4 m, the plot length as 8.1 m, and the plot area as 11.34 square meters. A 3 m gap was left between the plots with and without nematicide spraying. Nematicide application was made twice during the production season, just before planting potatoes and 1 month after planting potatoes. Routine maintenance, irrigation, and fertilization were carried out from planting to harvest. 70% Metribuzin was used for weed control; For potato beetle control, 200g/l Chlorantraniliprole and 25g/l Deltamethrin were used. After planting, according to Technical Instruction for Agricultural Measurement Trials (TTSM, 2001), 50% day of emergence, number of stems per plant, plant height, tuber maturation time, number of large tubers in total tubers, tuber yield per hectare were observed. Potatoes harvested from each plot were counted and weighed separately in 3 different sizes (35-55 mm, smaller than 35 mm, larger than 55 mm). In the study, tubers larger than 55 mm^3 were recorded as large tubers. The number of large tubers in total tubers on a plot basis and the % effectiveness degree between varieties were determined with the Abbot formula.

$$E = (NTL/TNT) \times 100.$$

E : % effect
NTL : Number of tubers larger than 55 mm^3
TNT : total number of tubers

Yield per hectare and percentage yield loss rates were calculated for all applications.

Statistical Analysis

Statistical analysis was carried out according to the randomized block design by applying the MSTAT-C statistical package program to the data obtained from the varieties in the plots with and without nematicide application. Data determined to be significant according to the variance analysis results were subjected to the Duncan multiple comparison test. The percentage of effect degree was calculated depending on the varieties.

Results and Discussion

50% Plant Emergence (day)

The variance analysis results applied to the 50% emergence day values showed that there were significant differences (P≤0.05) among the varieties (Muratbey and PAE13-08-07), while the nematicide treatments and interaction between treatments and variety interaction was found to be insignificant. Plant 50% plant emergence (day) of the varieties are given in Table 2.

In the plots where nematicide was applied, the earliest and latest emergence days were determined in Muratbey (18.5) and clone PAE-13-08-07 (22.5) respectively. In the plot where nematicide was not applied, Leventbey emerged at the earliest (19.0), and Bettina emerged at the latest (23.0). Researchers have reported that many factors directly or indirectly affect the emergence times of potato tubers (Yıldırım 2019). These are; soil structure, planting depth, climatic conditions, genetic structure. Physiological age also significantly affects the emergence time of potato tubers. They reported that there may be changes in emergence times due to the fact that potato tubers are of different sizes at the time of planting and do not have the same physiological age (Bülbül, 2018; Arslan, 2002). In potato, shoots emerge in approximately 15-30 days depending on the conditions and root formation begins in this period (Anonymous, 2024). Since the root density of the potato is low during the emergence period, nematicide uptake into the tuber body may not occur. A previous study, conducted by Kimpinski, et al. (2001) stated that a small significant negative nematicide effect on plant emergence 28 days after planting, with an mean emergence of 83.0 and 80.9% in the check and nematicide-treated parcels, respectively. The researchers also noted significant differences in plant emergence and plant vigour among the cultivars. As expected, early maturing varieties emerged rapidly than later maturing varieties. On the other hand, Norshie, et al. (2016) suggested that soil nematicide (fluensulfone) applications can protect potato plants from *G. pallida* infection. However, they reported that nematicide application did not have a significant effect on plant growth in one location in their study. Previous studies on this subject reported that soil application with nematicides did not always accompany improvements in potato growth and yield parameters, Evans et al. (2003); Whitehead et al. 1994). Soil p^h and plant nutrition were reported to be some of the factors suggested to affect potato responses to nematicide applications. In this study we conducted the effect of namaticide on the emergence period did not create any difference.

Table 2. Plant emergence (day) in potato varieties

Varieties	Nematicide Treated	Nematicide Untreated
Ünlenen	21.5 a-c	20.3 a-d+
Leventbey	19.0 cd	19.0 cd
Muratbey	18.5 d	19.8 b-d
PAE 13-08-07	22.5 ab	20.8 a-d
Desiree	21.3 a-d	19.8 b-d
Bettina	20.8 a-d	23.0 a
Mean	20.6	20.4

+) According to the Duncan test, means indicated with similar lower-case letters in the same column are statistically similar within the error limits of P ≤0.01 (50% plant emergence, LSD: 2.492, CV:9,06%, F value variety:3,45; treatment value:0,10)

Table 3. Number of shoots per plant in potato varieties

Varieties	Nematicide Treated	Nematicide Untreated
Ünlenen	6.47 ab	5.97 b-d+
Leventbey	4.53 c-e	4.32e
Muratbey	4.45 de	4.55 c-e
PAE 13-08-07	6.63 ab	6.80 ab
Desiree	6.05 bc	6.83 ab
Bettina	7.87 a	7.47 ab
Mean	6.00	5.99

+) According to the Duncan test, means indicated with similar lower-case letters in the same column are statistically similar within the error limits of P ≤0.01 (Number of shoots per plant LSD: 1.439, CV:10.01%, F value variety:36.80; treatment value:0.01)

Number of Shoots Per Plant

There was a significant difference (P ≤0.01) among the varieties regarding number of shoots per plant, while no significant difference was found in the treatment and variety treatment interaction. Number of shoots per plant of the varieties are given in Table 3.

Under nematicide treated conditions, the highest and lowest shoots were found in Bettina (7.87) and Muratbey (4.45), respectively. Untreated conditions, the lowest main stem number was found in the Leventbey (4.32), and the highest value was found in the Bettina (7.47).

The number of shoots per plant is affected by the number of buds per tuber, the damage rate of the shoots during planting, growth conditions, physiological age of the tuber, variety, tuber size, and soil conditions during sowing and emergence (Haverkort et al., 1990). Pszczolkowski and Sawicka (2017), reported that the shoot number each plant changed between 3.8 and 7.5, depending on the varieties. Ulutaş 2010, in her study, found that the number of main stems of potato varieties with nematicide application generally increased compared to those without. Significant differences were also found among varieties with nematicide application. In this study, although there were significant differences between varieties in both nematicide and non-nematicide application conditions, no significant difference was found between the applications. A study on this subject conducted by Ulutaş, (2010) stated that no difference in the number of main stems in the potato varieties Agria, Marabel, Marfona and Gronala in the fields infested with Golden Cyst Nematode, under nematicide-treated and non-treated conditions.

Plant Height (cm)

The results of variance analysis showed significant differences (P ≤0.01) among cultivar, treatment, and cultivar x treatment interaction regarding plant height. Plant heights of the varieties are given in Table 4.

Table 4. Plant height (cm) and % degree of impact in potato varieties

Varieties	Treated	Nematicide Untreated	% effect
Ünlenen	88.3 a +	75.25 bc	16.91
Leventbey	70.8 cd	65.8 de	7.72
Muratbey	65.8 de	64.0 e	7.34
PAE 13-08-07	56.3 fg	53.5 g	5.14
Desiree	79.3 b	61.3 of	29.38
Bettina	65.0 de	63.3 e	2.76
Mean	70.8 A++	63.8 B	11.0

+ According to the Duncan test, means indicated with similar lower-case letters in the same column are statistically similar within the error limits of P ≤0.01; ++) Means shown with similar uppercase letters in the same row are statistically similar within the error limits of P ≤0.05 according to the Duncan test. (Plant height LSD: 5.932,CV:6.10%, F value variety:36.89; treatment value:35.29)

Table 5. Plant maturity time(day) and % effect degree in potato varieties

Varieties			
	Nematicide Treated	Untreated	% effect
Ünlenen	121 ab	113 d+	7.07
Leventbey	122 ab	115 d	6.08
Muratbey	123 a	116 cd	6.03
PAE13-08-07	115 d	93 e	23.65
Desiree	119 bc	94 e	26.59
Bettina	124 a	119 bc	4.20
Mean	121 A++	108 B	12.04

+) According to the Duncan test, means indicated with similar lower-case letters in the same column are statistically similar within the error limits of P ≤0.01; ++) According to the Duncan test, the means shown with similar uppercase letters in the same row are statistically similar within the error limits of P ≤0.05. (Plant maturity LSD:3.22, CV:2.05%, F value variety:78.76; treatment value:352.18)

In terms of plant height, under nematicide-applied conditions, the shortest height was found in the PAE 13-08-07 (56.3 cm), Ünlenen (88.3 cm), and the most extended height was found in Ünlenen (88.3 cm) under nematicide applied conditions. The most extended plant height was found in Bettina (65.0 cm). The most affected cultivars were Desiree (29.38%), Ünlenen (16.91%), Leventbey (7.72%), Muratbey (7.34%), PAE 13-08-07 (5.14%) and Bettina (2.76%). The average plant height of all cultivars with and without nematicide applied was determined as 70.8 and 63.8 cm, respectively, and a significant difference was found between the treatments averages. In general, the plant height of potato varieties is shorter in control plots than in plots where nematicide application was made. Plant height is an important variety trait, although it is affected by factors such as day length, temperature, precipitation, soil moisture, planting density and fertilization (Tunçtürk et al., 2004). Trudgill, (1987), conducted on soil infested with PCN under nematicide and non-nematicide application conditions, he reported that the damage caused by PCN reduced the efficiency of the potato root system, leading to chronic deficiency of nutrients and consequently a decrease in top growth rate. Olthof (1989) also stated that nematicides (Metham-sodium, Oxamyl, and 1,3-D + aldicarb) applied reduces populations of *P. penetrans* in the roots and rhizosphere and increased plant vigor and potato yields relative to the control.

Plant Maturity Time (days)

As a result of variance analysis, significant differences (P ≤0.01) were determined among variety, application, and variety application interaction in plant maturity time. The maturity time and the % effect degree of the varieties are shown in Table 5.

Regarding plant maturity time, in treated condition, PAE 13-08-07 clone had the earliest (115) and this genotype was significantly differ from the other varieties. In contrast, the Bettina had the latest (124) plant maturity under nematicide application, Bettina, Muratbey, Leventbey, Ünlenen, and Desire matured later. However, in maturity time, no statistically significant difference was found among these varieties (except PAE 13-08-07). In the area where nematicide was not applied, PAE 13-08-07 matured the earliest (93) similar to Desiree while Bettina matured the latest (119). The average number of days to maturity per plant for all varieties studied under nematicide and non-nematicide applied conditions were 121 and 108 days, respectively, and a significant difference was found between the treatments. Desiree was the most affected with 26.59%, while the least affected was Bettina, with 4.20%. When the effect on plant maturity was examined, PAE 13-08-07 was listed as 23.65%, Ünlenen 7.07%, Leventbey 6.08% and Muratbey 6.03%. Trudgill (1987), stated that potato plants grown in soil heavily infested with PCN contained less N, P and K in their leaf dry matter compared to plants grown in the same soil and treated with nematicides. In general, the damage caused by the invasive PCN juveniles reduced the efficiency of the potato root system, leading to chronic deficiency of one or more nutrients and a consequent reduction in top growth rate and resulting in earlier harvest maturity of the plants. Similar results were found by Kaczmarek et al. (2019) and Ulutaş (2010). Our research findings revealed that nematicide applied to the soil increased the maturity period of potato varieties.

Number Of Large Tubers (number)

According to the variance analysis results, the ratio of large tubers to total tubers showed significant differences among varieties and treatments. The number of large tubers and the % degree of influence are given in Table 6.

Table 6. Large tubers and % degree of influence in potato varieties

Varieties	Nematicide Treated	Untreated	% effect
Ünlenen	51.0 b	42.3bc+	20.7
Leventbey	34.3 cd	30.5 dc	12.3
Muratbey	25.5 de	23.8 de	7.36
PAE13-08-07	27.5 de	25.0 de	10.0
Desiree	25.0 de	19.3 e	29.9
Bettina	63.8 a	62.0 a	2.82
Mean	37.8 A++	33.8B	11.8

+) According to the Duncan test, means indicated with similar lower-case letters in the same column are statistically similar within the error limits of P ≤0.01.; ++) Means shown with similar uppercase letters in the same row are statistically similar within the error limits of P ≤0.05 according to the Duncan test. (Number of large tubers). (CV:16.66%, F value variety:45.34; treatment value:4.39)

Table 7. Tuber yield(kg) and % degree of impact in potato varieties

Varieties	Treated	Nematicide Untreated	% effect
Ünlenen	38.500b	27.630cd+	39.3
Leventbey	34.380bc	28.550cd	21.8
Muratbey	33.400b-d	31.130b-d	7.9
PAE13-08-07	17.850e	15.130e	18.0
Desiree	26.080d	16.280e	60.2
Bettina	59.880a	57.700a	3.8
Mean	35.010A++	29.400B	19.1

+) According to the Duncan test, means indicated with similar lower case letters in the same column are statistically similar within the error limits of P ≤0.01; ++) Means shown with similar upper case letters in the same row are statistically similar within the error limits of P ≤0.05 according to the Duncan test.(CV:14.84%, F value variety:75.45; treatment value:16.55)

Nematicide application significantly increased the number of large tubers in varieties. The proportion of large tubers in total tubers was highest in Bettina (63.8) and lowest in Desiree (25.0) under nematicide and non-nematicide application conditions. Desiree was most affected by 29.9%, Bettina was least affected by 2.82%. Ünlenen was affected by 20.7%, Leventbey by 12.3%, PAE 13-08-07 by 10.0%, and Muratbey by 7.4%. Study indicated that the nematicide treatment significantly affected the large tuber proportion of the varieties. Reducing or eliminating the adverse effects of nematodes controlled by nematicide application provided better development of the varieties. Accordingly, the proportion of large tubers increased. In a similar study conducted by Ulutaş (2010) in nematode-infested fields, it was determined that the effects of Golden Cyst Nematode on tuber size varied according to the varieties under nematicide-treated and non-treated conditions, and the effects were 24.08%; 3.71%; 1.17% and 0% in Marabel, Marfona, Granola and Agria varieties, respectively.

Tuber Yield (kg/ha)

The variance analysis results applied to the tuber yields values showed that there were significant differences (P≤0.05) among the varieties, and nematicide treatments while the interaction between these two characteristics was statistically insignificant. Tuber yields of varieties and the percentage effects of applications on yield are shown in Table 7.

In the study, the lowest tuber yield in both treatments was determined in the PAE 13-08-07 (17.850 and 1513 kg/ha), while the highest yield was determined in the Bettina (59.880 and 57.700 kg/ha). Significantly higher tuber yields were obtained in varieties grown under nematicide applied than in unapplied conditions. Among the studied varieties, except the resistant control variety Bettina, the highest yield was found in Ünlenen (38.500 kg/ha) in the nematicide-applied area and Muratbey (31.130 kg/ha) in the untreated area. The average tuber yields of all studied varieties were found to be 35.010 and 29.400 kg/ha, respectively, and a significant difference was found between the treatments Table 7. Under nematicide-free conditions, the Desiree suffered the highest yield loss, 60.2%, followed by the Ünlenen, 39.3%. The lowest yield loss was determined in the Bettina with the 3.8%. Except for Desiree, the lowest yield loss among the examined varieties was determined in the Muratbey, with a rate of 7.9%. Significant increases were observed in tuber yields of varieties tested in plots where nematicide was applied. These findings show that the applied nematicide suppressed the nematode population in the plots. As a result, the tuber yield of all varieties examined in the study increased significantly compared to the plots without nematicide application. In areas infected with *Globodera* species, yield losses reach up to 70%, causing severe financial losses (Sparkes, 2013). Seenivasan (2017) observed 33.0% tuber yield loss due to natural populations of G. *rostochiensis* and *G. pallida* in a field study, which was preventable yield loss caused by natural PCN populations on potato. The research findings showed that *G. rostochiensis* Ro 2/3 race had a significant effect on the tuber yield of the potato varieties. It has been determined that as a result of nematicide application, the negative effects of nematodes controlled with nematicide application on the varieties decreased and tuber yields increased. Norshie et al. 2017. reported that nematicides with different active ingredient retarded root infection and population development of *G. pallida* in potato varieties, and tuber yield increased significantly in nematicide applications compared to the untreated control. Arntzen & Wouters (1994) observed significant differences in resistance in genotypes in plots with and without nematicides applied in the same field infested with nematodes.

Conclusion and Recommendations

As a result of this study conducted in Niğde province to determine the effects of potato cyst nematode on yield and plant development of potato varieties. In the experimental area, it was determined that Potato Golden Cyst nematode affected tuber yield, large tuber formation, maturation time and plant height at varying rates. It was determined that nematicide application was effective in increasing yield in all varieties. The higher tuber yield increase was detected in Desiree (60.2%), Ünlenen (39.3%) and Leventbey (21.8%), while the lowest increase was determined in Bettina (3.8%) and Muratbey (7.9%) varieties. Golden Cyst Nematode caused the most damage to potato plants in the form of tuber yield loss and an increase in the small tuber ratio. It was concluded that although nematicide application provided significant yield increases especially in varieties susceptible to nematodes, tuber yield losses could be reduced under conditions where nematicides were not applied by using nematode-resistant varieties.

Declarations

This study was presented at the 7th International Anatolian Agriculture, Food, Environment and Biology Congress, (Kastamonu, TARGID 2024)

Author Contribution Statement

Gülten Kaçar Avcı: Data collection, investigation, and writing the original draft

Halil Toktay : Review and editing, supervision,

Mustafa İmren: Data collection, review and editing, supervision.

G.Badel Akyol: Methodology, investigation.

Ramazan Canhilal: Project administration, supervision.

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Conflict of Interest

"The authors declare no conflict of interest."

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