Pakistan J. Zool., vol. 52(4), pp 1341-1346, 2020 DOI: https://dx.doi.org/10.17582/journal.pjz/20180523150551

Effects of Potato Cyst Nematodes on Three Potato Varieties in Algeria

Aouicha Djebroune[1]*, Aissa Mokabli[1], Miloud Hammache[2] and Gahdab Chakali[2]

[1]*Département des Sciences Agronomiques, Faculté des Sciences de la Nature et de la Vie et des Sciences de la Terre, Université de Khemis Miliana, Route de Theniet El Had, Ain Defla, Algeria*

[2]*Département de Zoologie Agricole et Forestière, Ecole Nationale Supérieure Agronomique, El-Harrach, 16200 Algiers, Algeria*

ABSTRACT

The potato cyst nematodes (PCN) *Globodera rostochiensis* and *Globodera pallida* are considered as being redoubtable pests of potato crop and are subject to strict quarantine regulations in several countries. In Algeria, the potato crop is the most important food crop widely cultivated in different agricultural areas. In this investigation, the response of three potato varieties; Kondor, Spunta and Desiree to the evolution of populations of *Globodera* spp. was studied. Final population of cysts, eggs and juveniles / kilogram of soil increased significantly in the variety Desiree compared to the initial population. A significant decrease was noticed in the variety Kondor. However, the variety Spunta did not show significance between the final and initial nematodes population. The effect of these nematodes on the tuber yield of various potato varieties was also studied. Variety Kondor produced the best yield while Desiree gave the least. The variety Kondor presented the best results in terms of resistance and yield. It is important to use this variety to control these pests.

Article Information
Received 23 May 2018
Revised 13 May 2019
Accepted 27 August 2019
Available online 31 March 2020

Authors' Contribution
AD designed the study, executed the experimental work and wrote the manuscript. AM and MH supervised the work. GC conducted the statistical analysis, corrected the manuscript and helped in orientation of the study.

Key words
***Globodera*, Potato, Crop yield, Algeria**

INTRODUCTION

The potato (*Solanum tuberosum* L.) is an important crop in Algeria. The area reserved annually for this crop is 85 000 hectares which is about 30% of the total area devoted to market gardening (Omari, 2011). However, potato production in Algeria has been constrained by several factors such as pests. Potato cyst nematodes (PCN) *Globodera rostochiensis* and *Globodera pallida* are a permanent risk around the world (Turner and Evans, 1998) and are subject to strict quarantine regulations in most countries (EPPO, 2013). *Globodera* species originate from the Andes (Evans and Stone, 1977) and were introduced into Europe around 1850 (Jones, 1970). From there, they spread through human activity over many areas. These nematodes significantly disrupt potato production in Algeria since 1953, date of his first discovery following the introduction of potato seeds from British origin at the end of the Second World War (Frézal, 1954). Recently, several studies were conducted in Algeria by the National Institute of Plant Protection that highlighted a presence of these biotic aggressors and their extension in notorious potato production areas i.e., Ain Defla, Tipaza, Chlef, Mascara and Setif.

* Corresponding author: djebrouneaouicha@hotmail.fr
0030-9923/2020/0004-1341 $ 9.00/0

Globodera species are subservient to a family of Solanaceae with a preference for potato, tomato (*Solanum lycopersicum* L.) and eggplant (*Solanum melongena* L.). In total, 90 potential species of the genus *Solanum* are recognized hosts of this group of nematodes (Bélair, 2005). They are sedentary endo-parasites inducing modified feeding sites called "syncytia" in root cells (Sobczak *et al*., 2005; Mukhtar, 2018). The nutritional activity of nematodes in roots causes significant damage: yellowing, wilting and growth retardation that results in small tubers (EPPO, 2004) and negative consequences on yield.

Potato cyst nematodes control remains difficult because of their chronological development that usually passes within the roots or in the cyst allowing excellent protection. An integrated approach can bring encouraging results. Chemical treatments are widely used, but they are generally expensive with environmental negative impacts (Evans *et al*., 2002). Several alternative approaches were used also to control nematodes in the infested areas, one of the most used techniques is the crop rotations with non-host that can reduce the infestations by these nematodes below the detection levels, but this method must be integrated with other methods to obtain a fast decrease in the population of nematodes (Brodie, 1996). In fact, these nematodes exhibit a well-developed strategy consisting of limiting their hatching and persisting in the soil in case of absence of their preferred host (Evans and Stone, 1977). In addition, the trap cropping can be used to reduce the

population of potato cyst nematodes by destroying them before the nematodes reach maturity (LaMondia and Brodie, 1986; Scholte and Vos, 2000), resulting in the infertility of eggs thus inducing hatching without the formation of new cysts, but this method requires adequate knowledge of the life cycle of these parasites. In this subject, Mimee *et al*. (2015) conducted their study in Quebec and were able to confirm that the proper timing for destroying potato trap crops was between 28 and 42 days after planting. Among all the control methods against the population of potato cyst nematodes, the preventive method, that is the use of resistant varieties, is considered to be the most recommended one.

Considerable economic loss of potato crop caused by *Globodera* cyst nematodes and lack of data on these parasites within its natural environment prompted us to undertake this study. The main objective was to gather information on the infestation dynamics of these nematodes on three potato varieties under natural conditions in order to better control their populations by practical actions and limit their damage within their distribution range in Algeria.

MATERIALS AND METHODS

Study site

The study was carried out in potato farms highly infested with nematodes in the area of Ain Defla. This region is an excellent area for potato crop, which is located in the North central part of Algeria (36° 19' 00''N, 2° 10' 00'' E) at an altitude of 980 m. This area is characterized by a semi-arid climate, with a very hot and dry summer and a cold winter, and an annual average precipitation between 500 and 600 mm. The potato has been grown mainly in monoculture or after a short rotation period with cereals (durum wheat, soft wheat, barley and oat).

The experimentation was done on three potato varieties (Kondor, Spunta and Desiree) which are commonly cultivated in the study region. The trial was conducted in 4 plots per variety with a surface of one hectare per plot. The soil type of the area site is loam-clayey, not compact and quite poor in organic matter.

The soil was tilled before planting using a plow followed by a cover-crop. Tubers were planted mechanically during early September 2012 with 75 cm spacing between rows and 25 cm on the row which gives a density of 52 000 plants per plot. During the growing season, various operations were performed according to farm protocol: fertilization, weeding, treatment against mildew and irrigation. Harvesting was done manually in early January of the following year (2013).

Measurements of potato yield parameters

During the month of January, ten plants were minutely removed randomly from each experimental plot to obtain reliable information on the host yield parameters, namely the number of tubers per plant and the weight of tubers. The yield was estimated by the average production of ten plants extrapolated to the total number of plants in the plot and expressed in t/ha.

Nematological analysis

This analysis included all plots to assess the infestation status of potato cyst nematodes. Soil sampling was conducted at two periods, at the end of August 2012, before planting to determine the initial population (*Pi*) and at the beginning of January 2013 (after harvest) to evaluate the final population (*Pf*). Samples were taken from 10-30 cm depth. A soil sample consisting of several elementary catches were collected from different places of the same plot in "Z"pattern (Coyne *et al*., 2010). Each sample was stored individually in a labeled bag. In the laboratory the soil samples were separately spread on paper to dry under natural conditions in a well-aired place for 5 days.

Globodera cysts were extracted from 1 kg soil samples using a modified container based on the Fenwick can technique (Fenwick, 1940) in particular based on flotation. Cysts were collected in sieve of 250 µm and transferred into filter paper, labeled and left to dry. The biological material is harvested using a fine brush under binocular loupe and kept batch in Petri dishes. The PCN cysts present in each extract were counted. In a second part, the cysts were crushed in isolation to count eggs and juveniles of second stage J2. Final and initial nematodes population (*Pi* and *Pf*) are expressed by the total number of cysts, eggs and juveniles J2 / kg of soil. The nematodes reproduction factor (*Rf*) was assessed as the ratio of *Pf* and *Pi*.

Statistical analysis

One-way analysis of variance (ANOVA) was used and results interpreted at the 5% of error threshold to test for the effect of potato varieties on the population of potato cyst nematodes and on multiplication rate of these pathogens. Averages potato yield parameters were also subjected to variances comparison in order to assess possible significance. All data analyzes were performed using STATISTICA (version 6.0).

Table I. Impact of potato varieties on population dynamics of potato cyst nematodes under the natural conditions (values of population density and reproduction factor of PCN presented as mean ± standard deviation).

Potato varieties	Initial population of cysts / kg of soil	Final population of cysts / kg of soil	P value	Initial population of eggs and J2/ kg of soil	Final population of eggs and J2/ kg of soil	P value	Reproduction factor of PCN
Kondor	6.50± 4.12	0.50± 0.57	0.027*	3000± 1859.92	97.5± 112.65	0.020 *	0.05±0.08
Spunta	2.75± 2.21	6.50± 5.06	0.223	1079± 1055.72	2388.25± 1925.82	0.278	2.57±1.50
Desiree	5.75± 3.68	21.5± 11.70	0.042 *	2840.25±1788.35	10035.25± 4981.66	0.034 *	4.04±1.30

P: probability; *: significant difference ($p<0.05$).

RESULTS

Population density of potato cyst nematodes

Results of population densities of *Globodera* spp., before planting and after harvest, of three potato varieties are given in Table I. A remarkable variation between the initial and final cyst populations was noticed. A significant decrease from 6.5 ± 4.1 to 0.5 ± 0.5 cysts / kg of soil was noticed in the variety Kondor. In contrary, the average values calculated were increased from 2.7 ± 2.2 to 6.5 ± 5.1 cysts for the variety Spunta. Similarly, for the variety Desiree, the level of population was increased significantly from 5.7 ± 3.6 to 21.5 ± 11.7 cysts. In regards to the total number of eggs and second-stage juveniles J2 / kg of soil, the comparison of the average initial and final population densities by analysis of variance highlighted a variation at the population level. A significant reduction in the attack density from 3000 to 97 individuals / kg of soil was noticed in the plot of the variety Kondor. A significant growth from 2840 to 10035 individuals / kg of soil was noticed in the plot for the variety Desiree. A slight growth in the population density of *Globodera* spp. was observed from the samples of the plot of the variety Spunta (from 1079 ± 1055.7 to 2388.2 ± 1925.8). The final populations did not differ significantly from the initial populations. Consequently, the analyses of nematodes multiplication rate on the different potato varieties highlighted a highly significant difference ($p = 0.002$). Indeed, this rate remains very high in the variety Desiree (4.04) and very low in the variety Kondor (0.05). While, the nematodes reproduction factor in the variety Spunta is 2.5.

Potato yield parameters

The influence of *Globodera* spp. on the yield parameters of the different potato varieties was studied during 2012. However, the analyses of the means showed abundance significantly different between the varieties. The tuber yield varied significantly ($p=0.008$) from 41.34 ± 3.51 to 53.95 ± 6.51 t / ha respectively for the varieties Desiree and Kondor (Fig. 1). The same trend was observed for the weight of tubers with a consequent difference ($p=0.018$) from 112 to 147 g on average for the varieties

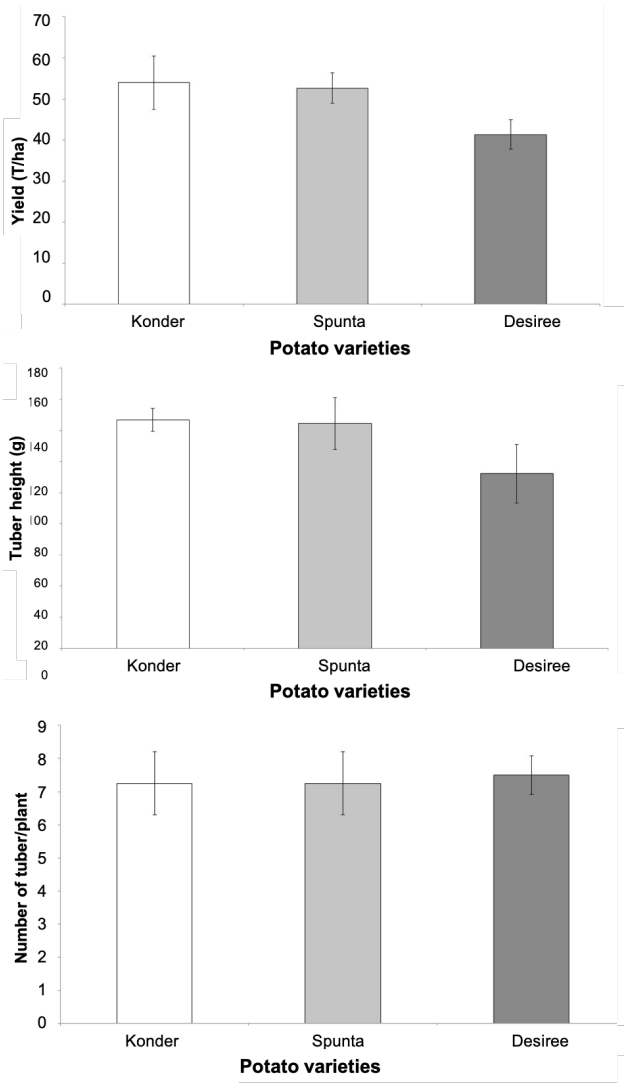

Fig. 1. Potato yield (A), Height of tubers (B), and number of tubes/ plant (C) in different potato varieties.

Desiree and Kondor (Fig. 1B). The number of tubers per plant of potato varieties did not differ significantly (p=0.892) (Fig. 1C).

DISCUSSION

Potato cyst nematodes are the most serious pests of potato production in Algeria, feeding upon roots as well as reducing potato yields. Increasing restrictions on the application of chemicals against nematodes will require the use of alternative methods to control such as long crop rotations, catch crops and the use of resistant cultivars (Fleming and Turner, 1998).

This study was to explore the impact of potato varieties on the abundance of Algerian populations of PCN during growing season under natural conditions. These findings confirmed those of other researchers like Urek *et al*. (2008) in Slovenia and Sudha *et al*. (2017) in Nilgiris. A significant difference for the multiplication rate of these nematodes on different potato varieties was noticed. The nematodes final population density decreased compared the initial density in the variety Kondor. The population density of PCN increased after the growing seasons for the varieties Spunta and Desiree. Differences in multiplication rates may be due to the genetic factors of the host which confers susceptibility or resistance as well as differences between nematode populations (Castagnone Sereno, 2006). The decline of the initial population density in plots of the variety Kondor might be explained by its resistance and low ability of the juveniles to multiply and develop to females. The increase in the number of cysts, juveniles and eggs in varieties Spunta and Desiree could be explained by their sensitivity towards these nematodes. Several investigations about this subject carried out by Evans (1993), Urek *et al*. (2008), Hadji hassani *et al*. (2013), Hajji-Hedfi (2017), Mezerket *et al*. (2018) showed that these two varieties are considered to be the most suitable hosts to the potato nematodes of the genus *Globodera*. High population densities of PCN (6.4 and 13.4 cysts per 100 cm^3 of soil) were determined in the Algerian plots of Desiree and Spunta respectively (Mezerket *et al*., 2018). Furthermore, other studies conducted by Urek *et al*. (2008) and Sudha *et al*. (2017) suggested that the initial population of potato cyst nematodes decreased in susceptible cultivars and increased in resistant ones.

Arntzen and Bakker (1988) reported that the difference in the number of cysts produced on susceptible potato cultivars were dependent of different potato cyst nematode species as well as on pathotypes and to some extent with different populations of the same pathotype. For example, potato cultivar Kufri Swarna is resistant to pathotype Ro1, 4, Pa2, 3 Pa2/3 but susceptible when tested with pathotype Ro5 (Sudha *et al*., 2016).

The reproduction of cyst nematodes on potato is usually associated with the production losses. This study also showed that these pests can significantly reduce the yield of the potato varieties tested. These results are in accordance with those obtained by Osypchuk *et al*. (2002), Urek *et al*. (2008) and Sudha *et al*. (2017). The significant results were obtained by the least multiplying variety of these phytophagous nematodes: Kondor. Susceptible varieties, Spunta and Desiree gave low yields. The decline of yield is relative to nematode population density at planting (Seinhorst, 1965; Trudgill *et al*., 1996), but is also attributed to the development of the nematode on the host (Hajihassani *et al*., 2013). The significant decrease of yields of the susceptible varieties found in the present study resulted from the penetration and the development of nematode juveniles in the roots which diminish the absorption capacity of water and nutrients by the plants. These results are comparable to those obtained in similar field experiments conducted with potato cyst nematodes by Urek *et al*. (2008) and Sudha *et al*. (2017). Otherwise, Barker and Koenning (1998) revealed that yield losses incurred in *Globodera rostochiensis*–susceptible potato averaged 38% (12-76%), compared to 18.3% (12-34%) in resistant potato.

The yield reduction of potato is affected by several factors such as cultivar, soil type, planting time, climatic conditions (Ehwaeti *et al*., 2000; Hockland, 2002) and interactions between these nematodes and fungal pathogens (Back *et al*., 2006).

In this study, the potato cyst nematodes not only affect the yield but also the average tuber weight. Urek *et al*. (2008) noted that the average tuber size is affected by *Globodera rostochiensis*. However, the effect of potato cyst nematodes on the number of tubers per plant of the varieties tested was insignificant.

CONCLUSIONS

In the light of the results, we consider that the potato cyst nematodes are highly influenced by the potato varieties. Our findings proved that the growth of resistant potato varieties, unlike sensitive ones, in the infested areas could present an effective management strategy against these pests. This approach allows to reduce sufficiently nematode populations and to minimize damage. The variety Kondor presented the best results in terms of resistance and yield. Therefore, this variety can be used in breeding programs to develop new resistant varieties against potato cyst nematodes.

ACKNOWLEDGEMENTS

Many thanks to Dr. Sara Hezil from *National Upper School of Agronomy, El-Harrach, Algiers, Algeria* and Dr. M'hamed El Mokhefi from *National Upper School of Veterinary, Rabie Bouchama, Algiers, Algeria* for the valuable comments in improving the manuscript.

Statement of conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Arntzen, F.K. and Bakker, J., 1988. Variation in number of cysts formed on susceptible potato cultivars with various populations of *Globodera rostochiensis* and *G. pallida*. *Euphytica*, **39**: 99-104. https://doi.org/10.1007/BF00043372

Back, M., Haydock, P. and Jenkinson, P., 2006. Interactions between the potato cyst nematode *Globodera rostochiensis* and diseases caused by *Rhizoctonia solani* AG3 in potatoes under field conditions. *Eur. J. Pl. Pathol.*, **114**: 215-223. https://doi.org/10.1007/s10658-005-5281-y

Barker, K.R. and Koenning, S.R., 1998. Developing sustainable systems for nematode management. *Annu. Rev. Phytopathol*., **36**: 165-205. https://doi.org/10.1146/annurev.phyto.36.1.165

Belair, G., 2005. Les nématodes, ces anguillules qui font suer les plantes... par la racine. *Phytoprotection*, **86**: 65-69. https://doi.org/10.7202/011717ar

Brodie, B.B., 1996. Effect of initial nematode density on managing *Globodera rostochiensis* with resistant cultivars and nonhosts. *J. Nematol.,* **28**: 510-519.

Castagnone-Sereno, P., 2006. Genetic variability and adaptive evolution in parthenogenetic root-knot nematodes. *Heredity,* **96**: 282-289. https://doi.org/10.1038/sj.hdy.6800794

Coyne, D.L., Nicol, J.M. and Claudius-Cole, B., 2010. *Les nématodes des plantes: Un guide pratique des techniques de terrain et de laboratoire*. Secretariat SP-IPM, IITA, Cotonou, Benin.

Ehwaeti, M.E., Elliott, M.J., Mcnicol, J.M., Phillips, M.S. and Turdgill, D.L., 2000. Modelling nematode population growth and damage. *Crop Prot.*, **19**: 739-745. https://doi.org/10.1016/S0261-2194(00)00098-3

EPPO, 2004. Diagnostic protocols for regulated pests, *Globodera rostochiensis* and *Globodera pallida*. PM 7/40 (1). *OEPP/EPPO Bull*., **34**: 309-314. https://doi.org/10.1111/j.1365-2338.2004.00734.x

EPPO, 2013. *Globodera rostochiensis* and *Globodera pallida*. PM 7/40 (3). *OEPP/EPPO Bull.,* **43**: 119-138. https://doi.org/10.1111/epp.12025

Evans, K., 1993. New approaches for potato cyst nematode management. *Nematotropica*, **23**: 221-231.

Evans, K., and Stone, A.R., 1977. A review of the distribution and biology of the potato cyst nematodes *Globodera rostochiensis* and *G. pallida*. *Int. J. Pest Manage.,* **23**: 178-189. https://doi.org/10.1080/09670877709412426

Evans, K., Webster, R.M., Halford, P.D., Barker, A.D. and Russell, M.D., 2002. Site-specific management of nematodes-pitfalls and practicalities. *J. Nematol,* **34**: 194-199.

Fenwick, D.W., 1940. Methods for the recovery and counting of cysts of *Heterodera schachtii* from soil. *J. Helminthol.,* **18**: 155-172. https://doi.org/10.1017/S0022149X00031485

Fleming, C.C. and Turner, J.S., 1998. Diagnostics of cyst nematodes: use of the polymerase chain reaction to determine species and estimate population levels. *Aspects appl. Biol.,* **52**: 375-382.

Frezal, P., 1954. Importance et répercussions de la contamination de l'Algérie par le nématode doré (*Heterodera rostochiensis* Wooll. [Woll.]. *J. C. R. Séanc. Acad. Agric. France,* **40**: 71-74.

Hajihassani, A., Ebrahimian, E. and Hajihasani, M., 2013. Estimation of yield damage in potato caused by Iranian population of *Globodera rostochiensis* with and without aldicarb under greenhouse conditions. *Int. J. Agric. Biol.*, **15**: 352-356.

Hajji-Hedfi, L., Hloua, W., Gamaoun, W., Chihani, N., Regaieg, H. and Horrigue-Raouani, N., 2017. Management of potato cyst nematode (*Globodera rostochiensis*) with Oxamyl. *J. New Sci., Agric. Biotechnol.*, CSIEA, 2591-2596.

Hockland, S., 2002. *Potato cyst nematodes- a technical overview for England and Wales*. CSL, Sand Hutton, York, England.

Jones, F.G.W., 1970. The control of the potato cyst-nematodes. *J. R. Soc. Arts,* **118**: 179-199.

Lamondia, J.A. and Brodie, B.B., 1986. The effect of trap crops and fallow on decline of *Globodera rostochiensis*. *Annls appl. Biol.,* **108**: 347-352. https://doi.org/10.1111/j.1744-7348.1986.tb07656.x

Mezerket, A., Hammache, M., Cantalapiedra-Navarrete, C., Castillo, P. and Palomares-Rius, J.E., 2018. Prevalence, identification, and molecular variability of potato cyst nematodes in Algeria. *J. agric. Sci. Tech*., **20**: 1293-1305.

Mimee, B., Dauphinais, N. and Bélair, G., 2015. Life

cycle of the golden cyst nematode, *Globodera rostochiensis*, in Quebec, Canada. *J. Nematol.,* **47**: 290-295.

Mukhtar, T., 2018. Management of root-knot nematode, *Meloidogyne incognita*, in tomato with two trichoderma species. *Pakistan J. Zool.,* **50**: 1589-1592. http://dx.doi.org/10.17582/journal.pjz/2018.50.4.sc15

Omari, C., 2011. La filière pomme de terre en Algérie. *Afri. Agric.,* **381**: 26-30.

Osypchuk, A.A., Taktaev, B.A., Sigareva, D.D. and Pylypenko, L.A., 2002. Breeding for resistance to the potato cyst nematode in Ukraine. *Czech J. Genet. Pl. Breed*., **38**: 158-159. https://doi.org/10.17221/6259-CJGPB

Scholte, K. and Vos, J., 2000. Effects of potential trap crops and planting date on soil infestation with potato cyst nematodes and root-knot nematodes. *Annls appl. Biol.,* **137**: 153-164. https://doi.org/10.1111/j.1744-7348.2000.tb00047.x

Seinhorst, J.W., 1965. The relation between nematode density and damage to plants. *Nematologica,* **11**: 137-154. https://doi.org/10.1163/187529265X00582

Sobczak, M., Avrova, A., Jupowicz, J., Phillips, M.S., Ernst, K. and Kumar, A., 2005. Characterization of susceptibility and resistance responses to potato cyst nematode (*Globodera* spp.) infection of tomato lines in the absence and presence of the broad-spectrum nematode resistance Hero gene. *Mol. Plant-Microb. Interac*., **18**: 158-168. https://doi.org/10.1094/MPMI-18-0158

Sudha, R., Venkatasalama, E.P., Bairwa, A., Bhardwaj, V. and Dalamu-Sharma, R., 2016. Identification of potato cyst nematode resistant genotypes using molecular markers. *Scient. Hort.,* **198**: 21-26. https://doi.org/10.1016/j.scienta.2015.11.029

Sudha, R., Venkatasalam, E.P., Mhatre-Priyank, H., Arti Bairwa, A. and Divya, K.L., 2017. Influence of potato cyst nematode infestation in different Potato Varieties. *Indian J. Nematol.*, **47**: 20-26.

Trudgill, D.L., Phillips, M.S. and Hackett, C.A., 1996. The basis of predictive modelling for estimating yield loss and planning potato cyst nematode management. *Pestic. Sci*., **47**: 89-94. https://doi.org/10.1002/(SICI)1096-9063(199605)47:1<89::AID-PS389>3.3.CO;2-J

Turner, S.J. and Evans, K., 1998. The origin, global distribution and biology of potato cyst nematodes (*Globodera rostochiensis* Woll. and *Globodera pallida* Stone). In: *Potato cyst nematodes: Biology, distribution and control* (eds. R.J. Marks and B.B. Brodie). CAB International, Wallingford, UK. pp. 7-26.

Urek, G., Širca, S., Geric Stare, B., Dolničar, P. and Strajnar, P., 2008. The influence of potato cyst nematode *G. rostochiensis* infestation on different potato cultivars. *J. Cent. Eur. Agric.,* **9**: 71-76.