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Development of Rhizoctonia Black Scurf of Potato in Relation to Tuber Borne Inoculum Density, Dehaulming Methods and Curing Time in Northwestern Alluvial Plains of India

Sandeep Jain[1] · Ritu Rani[1] · Pooja Salaria[1] · Simarjot Kaur[1]

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Abstract
To understand the effect of sclerotial density on tubers, and the method vis-a-vis timing of dehaulming on the development of black scurf, field studies were conducted under artificial epiphytotic conditions. Infection levels of up to 10% tuber coverage by scurf sclerotia (grades 0,1 or 2) did not affect yield, but tubers with more than 10% sclerotial coverage (grade 3 or higher) resulted in significantly lower yields compared to apparently healthy tubers (grade 0). The severity of the scurf was significantly higher when the tubers having up to 5% sclerotial coverage (grade 1) were used for sowing compared to sclerotia-free seeds. Seed tubers with more than 5% sclerotial coverage corresponding to grades 2, 3, and 4 of scurf severity were statistically at par with respect to scurf severity, but these had higher scurf intensity compared to grades 0 and 1 (sclerotial coverage 0–5%). The three test methods of dehaulming viz., cutting the tops, herbicide desiccation, and vine pulling didn't impact the overall tuber yield, but the timing of dehaulming i.e., 7,14,21, and 28 days before harvesting did impact the yield. There was a significant effect of the time gap between vine kill and harvest on the development of black scurf. Dehaulming conducted at 7 days before harvesting produced significantly higher yields than 14, 21, and 28 days before harvesting. The longer the time gap, the more severe was scurf infection. Using herbicide as a method of dehaulming led to more sclerotial formation compared to cutting and pulling.

Keywords *Solanum* · Vine kill · Seed · Sclerotia · Herbicide

Introduction

Production of high-quality seed potatoes requires proper tuber maturation at harvest which is one of the key factors in determining its seed quality. In potatoes, maturity is characterized by a peak in tuber-specific gravity, a desirable tuber size, and thickening and setting of the skin imparting resistance to fracture (Suslow and Voss 2000). During skin set the skin adheres to the underlying tissue and a waxy substance called suberin is synthesized, making tubers more resistant to skinning. It safeguards the tuber not only from water loss, but also from pathogen invasion, and its smooth visual appearance is crucial for deciding the market value of the crop. The potato seed industry is hampered by an economically important and global disease problem black scurf and stem canker caused by *Rhizoctonia solani* Kuhn (teleomorph: *Thanathephorus cucumeris* Frank Donk). The fungus limits the growth by forming cankers on sprouts, underground stems, and stolons, and makes tubers ugly by forming black sclerotia on tuber surfaces. The fungus can cause significant yield reductions (up to 34%) and can lead to significant changes in the shape and size distribution of tubers. Like other seed-borne pathogens (Slack 1993; Tsror et al. 1999), R. *solani* is transmitted by contaminated seed tubers, providing a mechanism for its long-distance dispersal. Further, once established in the soil, the mycelium and sclerotia of the pathogen may then provide an additional source of primary inoculum. Tuber-borne inoculum is considered to be more strongly associated with potato scurf than soilborne inoculum (Kempenaar and Struik 2007). Tuber maturity can be artificially induced by killing the haulms before harvest that protect potatoes from diseases, enhancing tuber shape,

✉ Sandeep Jain
sandeepjain@pau.edu

[1] Department of Plant Pathology, Punjab Agricultural University, Ludhiana, India

confining tuber size, and improving tuber release from the vine (Kempenaar and Struik 2007). There are three types of commonly used methods for dehaulming in India, namely, haulm cutting, haulm pulling, and haulm desiccation using herbicides. Whereas haulm cutting is a dehaulming method whereby a sharp object is used to cut off the vegetative part, haulm pulling is a method of detaching the foliage from the root tubers by pulling them using hands. Haulm desiccation uses chemical spraying herbicides on foliage which is absorbed into the plant system where it interferes with the physiological processes of the plant, eventually leading to its death. One drawback of chemical spraying as a method of dehaulming is that since the process is systemic (must be first absorbed into plant tissues before action) it does not kill plants instantaneously and takes time compared to the other methods. Dehaulming practice also plays a significant role in plant protection as various pathogen-carrying vectors can be avoided by dehaulming at the right stage which helps to produce disease-free tubers (Upadhyay and Bashyal 2020). Dehaulming methods that are used in potato production can affect the level of black scurf (Dijst et al. 1986). Dijst (1985) suggested that early haulm killing promotes the development of black scurf sclerotia. Advancing the killing of vines does not lead to a rapid disintegration of the roots. The initially fully functional root system continues to function as a water pump for about a week (Dijst 1985). As evaporation through the foliage ceases, tubers serve as a sink for the water surplus, consequently increasing in mass and commencing leakage. The use of herbicides and other chemicals to kill potato shoots just before harvest time can also lead to increased incidence and severity of black scurf on potato tubers (Mulder et al. 1992). As black scurf incidence has become so common in potato production systems that it is sometimes difficult to find adequate quantities of sclerotia-free seeds, the tolerance limit of sclerotia for seed tubers needs to be understood. Moreover, it's essential to assess black scurf development in relation to dehaulming methods and timings for quality seed production, given the lack of data on this aspect in the Indo-Gangetic plains. Even though some information exists regarding this aspect in Europe's temperate climate (Dijst et al. 1986; Dijst 1989; Bouman 1982; Kempenaar and Struik 2007), this research was specifically undertaken to fill the knowledge gap related to Indian tropical conditions. Its goal is to provide guidelines for enhancing seed tuber quality in the Indo-Gangetic plains. To address this issue, the present study was carried out to examine the effect of sclerotial density on tubers and the method and timing of dehaulming on black scurf development.

Materials and Methods

Site of Field Trials

The field trials were carried out at the Research Farm, Department of Plant Pathology, Punjab Agricultural University, Ludhiana, India during 2020-21 and 2021-22. The site is located at 30,535 N and 75,475 E with an altitude of 247 m above sea level in trans-Gangetic plains which represents the central region of Punjab. The field soil of the experimental area was loamy sand (79.8% sand, 12.2% silt, and 7.8% clay) with 7.5 pH, 179 kg ha^{-1} nitrogen, 0.42% organic carbon, 20 kg ha-1 phosphorus, and 144 kg ha-1 potassium. Pre-sowing irrigation (10–12 cm depth) followed by ploughing and leveling was done and well-decomposed farmyard manure (49.5 t ha^{-1}) was applied before sowing. Healthy potato seed tubers of 40–50 g weight @ 13–18 q/acre, were used for planting on ridges at the spacing of 20 cm in 1st fortnight of October 2021 and 2022. The crop was fertilized with 75 kg N (165 kg urea), 25 kg P_2O_5 (155 kg Single superphosphate), and 25 kg of K_2O (40 kg of Muriate of Potash) per acre. The fertilizers were drilled at the time of sowing as per the package of practices for vegetable crops recommended by PAU, Ludhiana (Anonymous 2020).

Field Trials with Different Densities of Tuber-Borne Inoculum

Seed tubers of the variety Kufri Pukhraj were manually graded for sclerotial coverage after taking out from cold storage. The effect of different densities of tuber-borne inoculum was evaluated by sowing different grades of tuber seed ranging from 0 to 4 grades described by Somani 1986 and yield data from different treatments were recorded. Standard agronomic practices were followed to raise the potato crop as per the recommended package of practices (Anonymous 2020). The grading of tubers based on sclerotial density was carried out using the scale, where grade 0 represented apparently healthy seeds, grade 1 represented tubers having a few small black sclerotia covering up to 5% surface area of tubers, grade 2 represented tubers having up to 10% of the tuber surface area, grade 3 represented tubers having up to 15% of the tuber surface area and in grade 4 tubers having more than 15% sclerotia were categorized.

Dehaulming was performed by cutting the vines 20 days prior to harvesting the tubers. The Percent disease index (PDI) was calculated at harvest using the formula:

$$PDI = [\text{sum (class frequency} \times \text{score of rating class)}]/[(\text{total number of samples observed}) \times (\text{maximal disease index})] \times 100$$

Field Trials for Evaluation of the Effect of Different Dehaulming Methods and Their Timings on Black Scurf and Seed Tuber Yield of Potato

The effect of different dehaulming methods and timings on yield and black scurf severity was evaluated under field conditions. The potato seeds used for sowing were of grade 2, covering 5–10% of the tuber surface area. The three dehaulming methods used were cutting the vines, herbicide desiccation, and pulling the tops and the timing interval for performing this process was 7, 14, 21, and 28 days before harvesting.

S.No	Method of dehaulming	Timing of dehaulming
1	Cutting the vines	7, 14, 21 & 28 days before harvesting in all of the three test dehaulming methods
2	Herbicide desiccation*	
3	Pulling the tops	

Data Analysis

The field trials on different densities of tuber-borne inoculum were laid out in randomized block design. The field trials on methods and time of dehaulming were laid out in a split-plot arrangement with three replications. The main plot consisted of dehaulming methods, while the time of dehaulming constituted sub-plots. The data was analyzed for Analysis of Variance using the software SPSS 16.0.

Results

Seed Tuber Inoculum Density Impacts Black Scurf Severity and Yield

The severity of black scurf varied from 4.67 to 45.05% during the 2020-21 period across different treatments containing seed tubers with varying levels of sclerotial intensity (Fig. 1). The lowest disease severity index (PDI) was seen in seed tubers classified as apparently healthy (grade 0), recorded at 4.67%. Following this, tubers with sclerotial coverage of up to 5% (grade 1) showed a PDI of 21.87%. Conversely, the highest PDI was observed in grade 4 tubers with sclerotial coverage exceeding 15%, reaching 45.05%. The apparently healthy seed tuber treatment (grade 0) was adjudged to be the best with the lowest severity of black scurf that was statistically superior to grade 1. The seed tubers belonging to grade 2, 3 and 4 categories were statistically at par with each other in terms of percent disease index of black scurf. Similarly, the data from the second season trials during 2021-22 exhibited a similar trend. The percent disease index (PDI) of the treatments, ranging from sowing grade 0 to 4, showed black scurf indices ranging from 6.38 to 48.71%. The minimum PDI was exhibited in grade 0 (6.38%) followed by grade 1 (25.68%) and the maximum PDI was found in plants sown with grade 4 (48.71%).

In terms of yield, different levels of sclerotial density provided yield ranging from 23.02 to 36.98 tonnes/ha with the maximum yield in grade 0, and the minimum yield was found in plants sown with grade 4 during 2020-21. Grade 0 and 1 were statistically at par with each other whereas grades 2, 3, and 4 differed statistically in 2020-21 and 2021-22. During the second season trials, the tuber yield ranged from 21.83 to 36.04 tonnes/ha in which the maximum yield was found in the case of grade 0 (36.04 tonnes/ha), and the minimum yield was found in treatment sown with grade 4 (21.83 tonnes/ha). Within the different treatments of grades 0 to 4, the treatment means denoted by distinct letters varied significantly (Figs. 1 and 2).

Method of Dehaulming as well as Timing Impact Black Scurf Severity and Yield

In 2020-21, the percent disease index (PDI) recorded for plants desiccated using three different dehaulming methods viz., cutting, pulling, and herbicide treatment ranged from 23.00 to 47.00%. The lowest disease index was observed in pulling treatment 7 days before harvesting (DBH),

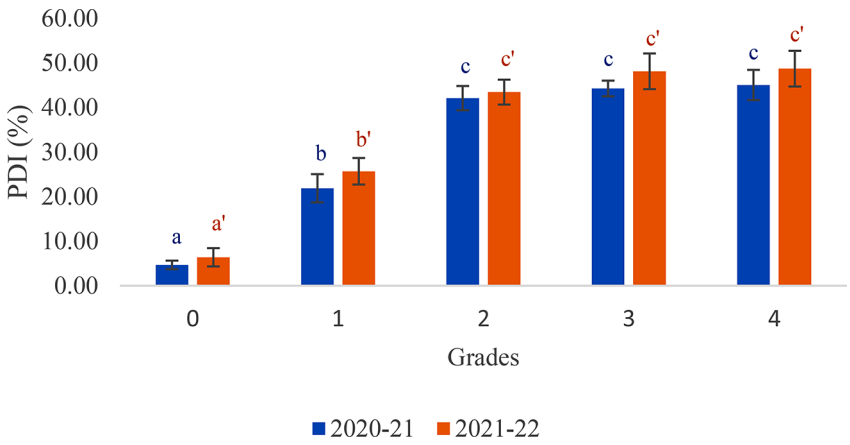

Fig. 1 Black Scurf Index (PDI) in response to seed tubers with different grades of severity during 2020-21 and 2021-22. The letters **a**, **b** & **a'**, **b'** depict the significant difference in PDI of different grades (0–4) in the year 2020-21 and 2021-22, respectively

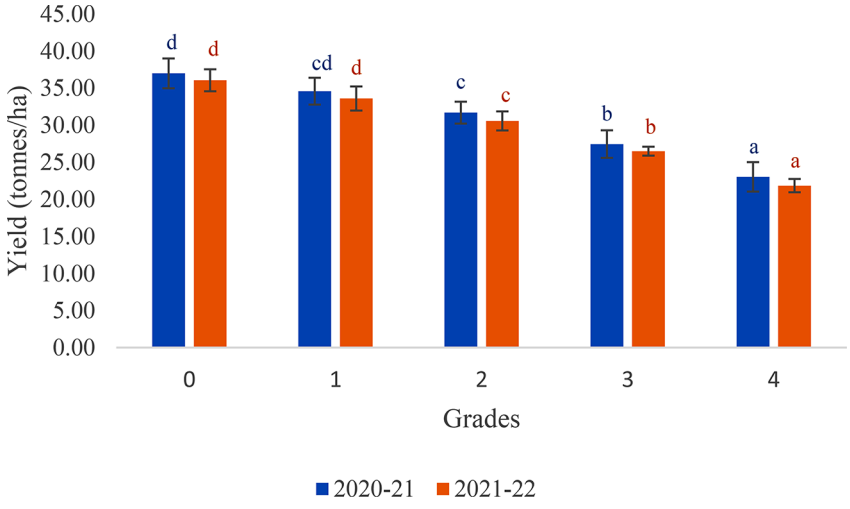

Fig. 2 Tuber yield in response to seed tubers with different grades of severity during 2020-21 and 2021-22. The letters **a**, **b** & **a'**, **b'** depict significant difference in yield of different grades (0–4) in the year 2020-21 and 2021-22, respectively

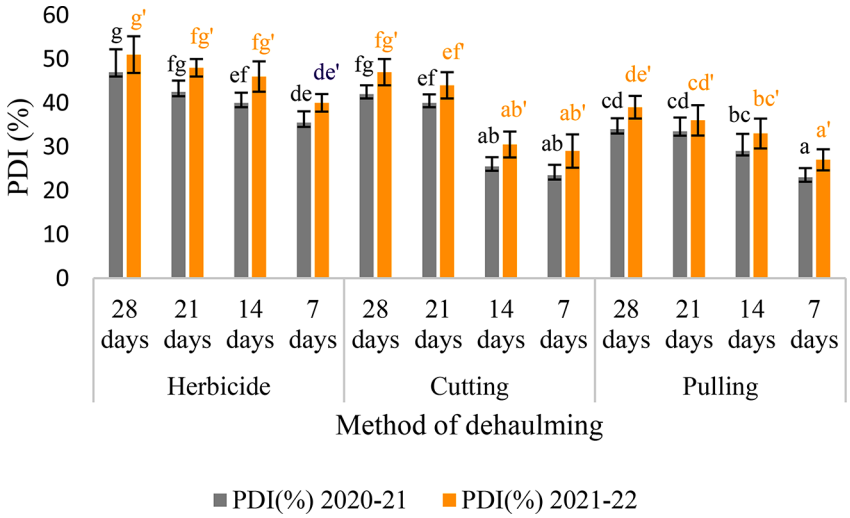

Fig. 3 Black Scurf Index (PDI) in response to methods of dehaulming and their timing during 2020-21 and 2021-22. The letters **a**, **b** & **a'**, **b'** depict significant difference in PDI of different dehaulming methods in the year 2020-21 and 2021-22, respectively

with a PDI of 23.00%, followed by plants cut at 7 DBH (23.50%) and 14 DBH (25.50%). Conversely, the highest black scurf intensity was observed in the case of dehaulming by herbicide carried out at 28DBH (47.00%). In terms of yield, it ranged from 19.07 to 30.60 tonnes/ha in which the maximum yield was found in the treatment of plants cut at 7 DBH, and the minimum yield was found in plants desiccated by pulling at 28 DBH. Similarly, in 2021-22, the PDI of plants desiccated by three methods ranged from 27.00 to 51.00%. The minimum PDI was exhibited in the case of vines that were pulled 7 days before harvesting (DBH) with a PDI of 27.00% followed by plants cut at 7DBH (29.00%) and 14 DBH (30.50%). The maximum PDI was observed in plants dehaulmed by herbicide treatment performed at 28DBH (51.00%). During 2021-22, the yield ranged between 20.41 and 31.94 tonnes/ha in which the maximum yield was found in plants desiccated by cutting at 7DBH, and the minimum yield was found in plants pulled at 28 DBH. So, it was concluded that both in 2020-21 and 2021-22, in terms of PDI, the treatment of pulling at 7 DBH was at par with the treatment of cutting at 7 and 14 DBH. The treatment of pulling at 14 DBH was at par with the treatment of cutting at 7 and 14 DBH. In terms of yield, the treatment of cutting exhibited maximum yield at 7 DBH which was statistically higher than other treatments whereas, the treatment of pulling at 7 DBH, cutting at 14 DBH, and herbicide desiccation at 7 DBH were statistically at par in both the years. Within the different methods of dehaulming, the treatment means denoted by distinct letters varied statistically which clarifies the variation between different treatments (Figs. 3 and 4). In summary, the findings indicated that herbicide desiccation treatment resulted in the highest severity of black scurf, followed by cutting and pulling. This implies that employing herbicide for dehaulming potato vines exacerbates the severity of black scurf disease. To alleviate the scurf disease, potato growers would benefit more from utilizing mechanical methods like pulling and cutting for dehaulming.

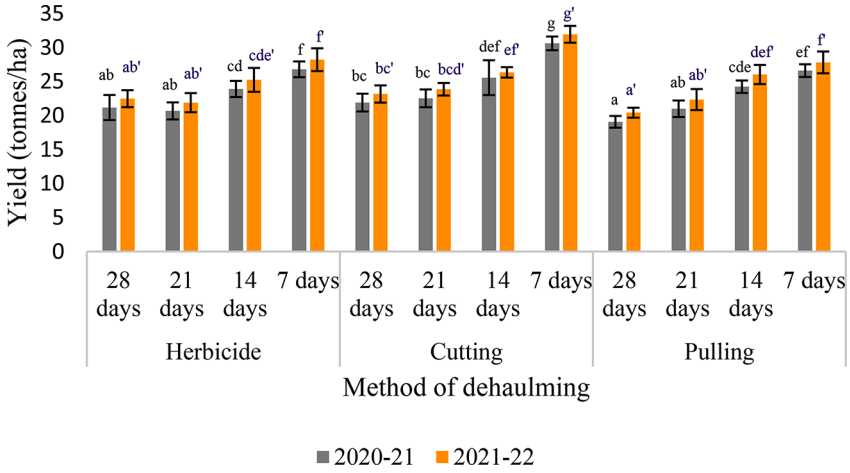

Fig. 4 Tuber Yield in response to different methods of dehaulming and their timing during 2020-21 and 2021-22. The letters **a**, **b** & **a'**, **b'** depict significant difference in yield of different dehaulming methods in the year 2020-21 and 2021-22, respectively

Discussion

Haulm destruction represents a dramatic event in the life cycle of a potato tuber, particularly for seed potatoes. This treatment is conducted when the haulm is still highly active, and tuber bulking is occurring rapidly. Killing haulms serve various purposes in potato seed crop management, including inducing tuber maturation, reducing the risk of virus spread, optimizing tuber size distribution, and easy harvesting. The present study seeks to establish tolerance for black scurf disease caused by *Rhizoctonia solani* and investigate the most commonly employed dehaulming practices in potato, focusing on the development of black scurf in Indian conditions. It has emerged from the present research that it is best to plant seed tubers devoid of *Rhizoctonia* sclerotia. However, in emergent situations where black scurf is present on seed tubers and no alternative is available, it is imperative to ensure that the sclerotial coverage never exceeds 5% (grade 1). Adhering to this finding is also crucial for averting substantial yield penalties and minimizing the impact of scurf severity on progeny tubers. Further, the black scurf formation is influenced by the method of haulm killing and its timing. The Chemical desiccation of haulms (Paraquat dichloride 24% SL) led to higher scurf severity compared to mechanical methods of haulm cutting and pulling. As the time interval between haulm destruction and harvest increases from one to four weeks, scurf severity increases. Restricting the curing period to less than 14 days is helpful in scurf containment. After chemical treatment, haulms die back slowly and as the plant begins to die, the fungus initiates the formation of sclerotia on tubers (Johnson 2003). It is believed that different methods of haulm killing may induce different alterations in tuber exudate and periderm. After chemical haulm destruction, the flow of sap from roots to tubers persists for about a week. Additionally, more liquid and precipitable substances are exuded from the tubers after herbicide application. This increased exudation may contribute to the formation of black scurf (Dijst 1989). The longer the potatoes remain in the soil after vine kill, the more sclerotia are formed on the tubers. Further, the results of the present study corroborate the findings of Gudmestad et al. 1979; Dijst 1989; Kempenaar and Struik 2007 and Bouman 1982. Since the information on this aspect was lacking under Indian tropical conditions, the data generated in this research will contribute to producing better quality scurf-free seed tubers in the Indo-Gangetic plains of India.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12230-024-09958-2.

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Data Availability Data will be made available on request.

Declarations

Competing interests The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Anonymous. 2020. *Package of practices for cultivation of vegetables*. 107. Ludhiana: PAU.

Bouman, A., and J. Bouma. 1982. *The effect of the potato haulm on the haulm pulling efficiency*. 30. IMAG- Research Report 82–1.

Dijst, G. 1985. Investigations on the effect of haulm destruction and additional root cutting on black scurf on potato tubers. *Netherlands Journal of Plant Pathology* 91: 153–162.

Dijst, G. 1989. The effect of chemical haulm destruction and haulm pulling on potato black scurf caused by *Rhizoctonia solani* AG-3. Thesis Agricultural University 1989, Wageningen, 70 pp.

Dijst, G., A. Bouman, A. Mulder, and J. Mulder. 1986. Effect of haulm destruction supplemented by cutting off roots on the incidence of black scurf and skin damage, flexibility of harvest period and yield of seed potatoes in field experiments. *Netherlands Journal of Plant Pathology* 92: 287–303.

Gudmestad, N. C., R. T. Zink, and J. E. Huguelet. 1979. The effect of harvest date and tuber-borne sclerotia on the severity of Rhizoctonia disease of potato. *American Potato Journal* 56: 35–41.

Johnson, S. B., and S. S. Leach. 2003. *Rhizoctonia diseases on potatoes. Bulletin 2273*. University of Maine Cooperative Extension.

Kempenaar, C., and P. C. Struik. 2007. The Canon of Potato Science: Haulm Killing. *Potato Research* 50: 341–345.

Mulder, A., L. J. Turkensteen, and A. Bouman. 1992. Perspectives of green-harvesting to control soil-born and storage diseases of seed potatoes.

Slack, S. A. 1993. Seed certification and seed improvement programs. In *Potato Health Management*, ed. R. C. Rowe. 61–65. St Paul, MN, APS.

Somani, A. K. 1986. Control of black scurf (*Rhizoctonia Solani*) and common scab (*Streptomyces scabies*) of potato (*Solanum tuberosum*). *Indian Journal of Agricultural Science* 56: 693–698.

Suslow, T., and R. Voss. 2000. *Potato, early crop: recommendations in maintaining postharvest quality*. Davis CA: Postharvest Technology Univ. of Calif.

Tsror, L., O. Erlich, and M. Aharon. eds. 1999. A survey of bacterial and fungal seed-borne diseases in imported and domestic potato seed tubers. *Phytoparasitica* 27: 215–226.

Upadhyay, A., and S. Bashyal. 2020. Effects of Dehaulming in Potato (*Solanum tuberosum*) cultivation: a review. *International Journal of Environment Agriculture and Biotechnology* 5(4): 0994–1000.