Plant Protection, 09 (03) 2025. 609-622 DOI:10.33804/pp.009.03.5719



Available Online at EScience Press
Plant Protection
ISSN: 2617-1287 (Online), 2617-1279 (Print)
http://esciencepress.net/journals/PP

Research Article

# Assessment of the Impact of Certified and Uncertified Potato Seed Tubers on Yield, Quality, and Disease Incidence in Lesotho

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**ARTICLE INFO**

***Article history***
*Received: 26th May, 2025*
*Revised: 15h August, 2025*
*Accepted: 18th August, 2025*

***Keywords***
*Potato*
*Seed-borne pathogens*
*Asymptomatic tubers*
*Atypical symptoms*
*Certified seed*

**ABSTRACT**

Potato production is severely affected by seed-borne diseases; hence, the use of disease-free seed tubers is crucial for yield and quality. This greenhouse study compared certified disease-free and uncertified symptomatic seed tubers for yield traits (size, number, and weight) and disease incidence (DI) and severity (DSI) in progeny tubers. Fungal pathogens were isolated from symptomatic seed tubers and cultured on potato dextrose agar (PDA) to determine the causal agents of blemishes. Colony morphology, mycelial characteristics, and the presence or absence of constrictions were assessed visually and microscopically from thirty isolates. Molecular characterization of twenty isolates was performed by rDNA sequencing of the internal transcribed spacer (ITS) region and elongation factor 1-alpha (EF1-α). Distinct colony colors, mycelial textures, growth patterns, macroconidia shapes, and constrictions were observed among the isolates. In total, five prevalent diseases and six causal pathogens were identified viz., *Rhizoctonia solani*, *Fusarium oxysporum*, *F. longifundum*, *Phytophthora infestans* and *Colletotrichum coccodes*. The results revealed significant differences ($P < 0.005$) in tuber size distribution, with asymptomatic seed tubers producing more medium- and large-sized tubers, whereas symptomatic seed tubers produced a higher proportion of small-sized tubers. The total tuber number (9.6 vs. 7.2) and tuber weight (204.5 g vs. 123 g) were also significantly higher ($P < 0.005$) in asymptomatic seed tubers compared to symptomatic ones. Moreover, symptomatic seed tubers exhibited markedly higher DI (47.6%) and DSI (35.0%) compared with asymptomatic seed tubers (11.8% DI and 10.6% DSI).

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## Introduction

Potato (*Solanum tuberosum* L.) is one of the most important staple food crops worldwide, contributing significantly to both food and nutritional security. Potato production plays a vital role in sustaining rural livelihoods and serves as a valuable crop for direct consumption as well as for market sales, particularly in many developing countries, including Lesotho. However, tuber yield and quality are strongly influenced by a range of biotic and abiotic factors, among which seed-borne diseases are particularly critical.

Seed-borne diseases, caused by diverse pathogens such

as viruses, bacteria, and fungi, are among the major constraints to potato productivity. These diseases can substantially reduce both yield and quality, especially when farm-saved seed tubers are reused for multiple planting seasons without appropriate disease management interventions (Tsegaye et al., 2019; Tuquerrez et al., 2023). Continuous recycling of seed tubers from informal or uncertified sources promotes the accumulation of pathogens in seed stocks, leading to a progressive decline in yield over time (Gildemacher et al., 2011). Consequently, seed quality is a key determinant of both productivity and marketability. Numerous studies have emphasized the critical role of high-quality seed in crop performance. For instance, Mekonnen (2020) reported that seed quality alone can account for an 18-20% yield increase when other production factors remain constant. This highlights the need for improved seed systems to enhance both productivity and resilience in potato farming. The use of certified seed tubers, free from pathogens and physiological defects, has been shown to increase yields and reduce disease incidence (Adane, 2013; Zhang et al., 2023).

Seed-borne pathogens not only persist in seed tubers across growing seasons but can also infect emerging plants soon after planting, resulting in poor stand establishment, stunted growth, and reduced vigor (Martin et al., 2020; Mekonnen, 2020). Common pathogens such as *Fusarium sambucinum* and *Rhizoctonia solani* affect tuber health both in storage and after sowing, leading to delayed emergence or complete loss of sprouts (Wharton and Kirk, 2007; Rakibuzzaman et al., 2021). The rapid spread and persistence of these pathogens highlight the importance of planting disease-free seed for successful potato production.

The informal seed supply system is the predominant channel for acquiring seed potatoes in Lesotho, as smallholder farmers typically store their own seed at the farm level. When on-farm stocks are insufficient, they supplement them with seed obtained from alternative sources such as local markets and neighboring farmers. A small proportion of farmer groups or associations purchase seed stock from South Africa, which they multiply and distribute as generation two or three seed potatoes to other farmers (Molahlehi et al., 2013). Seed potatoes sourced through informal channels are of unknown quality, and crop performance is often suboptimal. The continued reliance on farm-saved seed without periodic renewal from formal supply systems is largely due to the limited accessibility of improved and certified seed, primarily constrained by the low purchasing power of smallholder farmers. This practice results in reduced yields and accelerated seed degeneration, mainly due to the accumulation of seed-borne diseases (Gildemacher et al., 2007; Thomas-Sharma et al., 2015). However, limited research has compared the performance of different seed sources with respect to disease incidence, yield, and tuber quality under local growing conditions. Therefore, this study examined the impact of microbial pathogens on the quality, yield, and yield components of potato progeny tubers derived from different seed sources commonly used by smallholder farmers in Maseru Urban, Lesotho, emphasizing the importance of using certified diseases free seed tubers from formal sources to achieve better productivity and reduce diseases impact in potato cultivation.

## Materials and Methods

### Study area

The study was conducted from November 2023 to May 2024 in the experimental greenhouse and laboratory of the National University of Lesotho, located in Roma, Maseru District, the capital of Lesotho. Roma is a rural settlement situated approximately 34 km southwest of Maseru, at latitude -29.44667 and longitude 27.70806.

### Sample collection

Potato seed tubers displaying visible atypical disease symptoms were purchased from street vendors within the Maseru district (Figure 1; Table 1). These tubers represented farm-saved or recycled seed commonly used by local smallholder farmers. In contrast, certified disease-free seed tubers, free from visible symptoms, were procured from a formal supplier in South Africa and served as the control. All collected tubers were stored in a dark, well-ventilated storeroom under ambient conditions to promote sprouting prior to planting.

### Fungal isolation and morphological identification of isolates

Sections of infected leaf and tuber tissues were cut and surface-sterilized by immersion in 1% sodium hypochlorite (NaOCl) for one minute, followed by rinsing with sterile distilled water. The samples were then dried on sterile blotter paper. For fungal isolation, Potato Dextrose Agar (PDA) was used (Uthayasooriyan et al., 2016). Sections of infected tissue were placed onto Petri dishes containing PDA supplemented with streptomycin sulfate (0.05 g/L) under aseptic conditions in a laminar

airflow cabinet (Hlaiem, 2021). The plates were sealed with parafilm to prevent contamination and incubated at 25°C for approximately seven days, with daily observations for pathogen growth.

Figure 1. Potato seed tubers exhibiting atypical superficial blemishes and defects collected from street vendors within the Maseru district.

Table 1. List of collected potato seed tuber samples exhibiting atypical disease symptoms.

| Sample ID | Cultivar | Disease | Symptoms | Source | Reference |
|---|---|---|---|---|---|
| PEH1; PEH2 | Mondial | Elephant hide | Corky dark polygonal brown scab lesions | Potato tubers | Gush et al., 2019; Muzhinji et al., 2014 |
| PEH3 | Mondial | Growth cracks | Corky cracks with elephant hide | Potato tubers | Gush et al., 2019; Zimudzi et al., 2017; |
| BLS1; BLS2; BLS3 | BP1 | Black scurf | Small crust like bodies with dark or black sclerotia | Potato tubers | Mothibeli et al., 2023 |
| PDR1; PDR2; PDR3; PDR4; PDR5 | Mondial | Dry rot | Sunken and wrinkled brown to black tissue spots on tubers | Potato tubers | Kim et al., 2023; Xue et al., 2023 |
| PBD1; PBD2; PBD3 | BP1 | Black dot | Several black dots or black sclerotia and brown to greyish blemishes | Potato tubers | Sanzo-Miró et al., 2023; Dennis et al., 2018 |
| PLB1; PLB2; PLB3; PUN1 | Mondial | Late blight | Dark brown to purplish black spots extending several centimeters into the tubers, brown discoloration of the flesh and hard depressions including purplish tinge on the sides. | Potato tubers | Lal et al., 2018; Jean et al., 2018; Tsedaley, 2014; Jean et al., 2018 |

Morphological characteristics such as colony color, number of colonies, and growth patterns were recorded for each pathogen. On the seventh day, visual and microscopic observations were made to identify morphological features based on colony appearance on PDA and hyphal structures under a microscope.

To study hyphal morphology, seven-day-old mycelia grown on PDA were mounted on microscopic slides, stained with 0.1% lactophenol cotton blue, and examined for characteristics such as branching angle and septation (Bindu et al., 2017). Observations were made using a light microscope at 40× and 100× magnifications, equipped with a camera. Pure cultures were preserved at 4°C for subsequent DNA extraction

and molecular characterization by rDNA sequencing at Inqaba Biotechnologies, Pretoria, South Africa.

**Molecular identification of fungal species**

**DNA extraction**

Mycelia were scraped from three-day-old cultures using a sterile scalpel and processed for DNA extraction using a Zymo Research kit according to the manufacturer's protocol. Genomic DNA was extracted from 20 representative isolates. DNA concentration and purity were determined using a NanoDrop 2000c Spectrophotometer (Thermo Scientific, Waltham, MA, USA).

**Polymerase chain reaction (PCR) amplification and sequencing**

PCR reactions (50 µl total volume) consisted of 10 ng/µl DNA template, 10× Taq Reaction Buffer, 10 µM primers (3 µl each), 10 mM dNTPs (1 µl), Taq DNA Polymerase (4 µl), and nuclease-free water (32 µl). Cycling conditions were: initial denaturation at 94°C for 2 min; 40 cycles of denaturation at 94°C for 30 sec, annealing at 54°C for 1 min, and extension at 72°C for 2 min; followed by a final extension at 72°C for 7 min. The ITS rDNA region was amplified using primers ITS1 and ITS4 (White et al., 1990), while the tef1 region was amplified using primers EF1 and EF2 (O'Donnell et al., 2022). Additional PCR conditions for tef1 included: initial denaturation at 94°C for 2 min, followed by 35 cycles of denaturation (94°C, 30 sec), annealing (56°C, 90 sec), and extension (68°C, 3 min), with a final extension at 68°C for 5 min. Amplicons were visualized on 1.5% agarose gels, purified using a Zymoclean™ Gel DNA Recovery Kit (USA), and sequenced bidirectionally using an ABI 3730xl sequencer (Applied Biosystems, USA) with BigDye Terminator v3.1 chemistry.

**Fungal identification and phylogenetic analysis**

Forward and reverse sequences were assembled into consensus sequences using BioEdit v7.0.5.3 (Hall, 1999). Species identification was confirmed through BLASTn analysis of the ITS, tef1-α, and rpb2 sequences against the NCBI GenBank database. Multiple sequence alignments were generated using MAFFT v7 (http://mafft.cbrc.jp/alignment/server/index.html), with gaps treated as missing data. Phylogenetic analyses were conducted separately for *R. solani* and BNR datasets using maximum parsimony (MP) in PAUP v4.0* (Swofford, 2000) and maximum likelihood (ML) in PhyML 3.0 (Guindon and Gascuel, 2003).

In MP analysis, heuristic searches with 100 random sequence additions, tree bisection-reconnection (TBR) branch swapping, MULPAR effective option, and auto-increasing MaxTrees were used. Consistency (CI) and retention (RI) indices were calculated, and bootstrap analysis (1,000 replicates) was performed to assess branch support. For ML analysis, the best-fitting nucleotide substitution models were determined using jModelTest v2.1.7 (Darriba et al., 2012) under the Akaike Information Criterion. The TPM2uf+I+G model was used for *R. solani*, and the TIM3+G model for BNR datasets. *Thanatephorus cucumeris* AG-1-IB (AY154302) was used as the outgroup (Kiliçoğlu and Özkoç, 2013). All phylogenetic trees were edited using FigTree v1.3.1 (http://tree.bio.ed.ac.uk/software/figtree/).

**Plant material**

The experiment was conducted under greenhouse conditions at 22 ± 2°C, with irrigation every 3-4 days. Sandy loam soil was collected from the NUL farm, sterilized by autoclaving at 121°C for 60 min, and used to fill 30 cm diameter plastic pots. Each pot received 300 g of sterile soil before planting a single sprouted seed tuber, which was then covered with an additional 300 g of sterile soil. Basal fertilization was applied at planting using NPK (2:3:2, 14) Wonder fertilizer.

The experiment followed a Randomized Complete Block Design (RCBD) with six treatments (including the atypical symptom groups; Table 1) and five replications. Each replication contained three plants per treatment. Certified disease-free (asymptomatic) seed tubers served as control plants. The design minimized bias and accounted for environmental variability, and the experiment was repeated twice.

**Data collection**

Data were collected at harvest from progeny tubers. The number of tubers per pot was recorded, and each tuber's diameter was measured with a ruler and classified as small (< 35 mm), medium (35-55 mm), or large (> 55 mm) (Kigambo et al., 2023). Tuber weight (g) was measured using an electronic balance, and the total weight per pot was calculated.

For disease assessment, five washed tubers were randomly selected from each pot. Disease incidence (DI) and disease severity index (DSI) with the disease rating scale shown in Table 2 were calculated using the formulas described by Ahmed et al. (1995).

$$\mathrm{DI} = \frac{\text{Number of infected tubers}}{\text{Total No. of tubers examined}} \times 100$$

$$\mathrm{DSI} = \frac{(\text{Number of tubers in each rating} \times \text{rating})}{\text{Total number of tubers examined}} \times 100$$

Table 2. Disease severity of each tuber, scored for elephant hide, black scurf, dry rot, and black dot using a 0-5 disease rating scale (Ahmed et al., 1995).

| Area affected | Disease rating |
|---|---|
| No symptoms | 0 |
| <1 % | 1 |
| 1-10% | 2 |
| 11-20% | 3 |
| 21-50% | 4 |
| More than 50% | 5 |

**Statistical analysis**

The collected data were cleaned, averaged across the two trials, and subjected to analysis of variance (ANOVA) using the Statistix 10.0.0.9 software package to determine the effects of seed health on potato tuber size distribution, tuber weight, total tuber number, disease incidence, and disease severity index. Homogeneity of variances was assessed using Bartlett's test ($\alpha = 0.05$), and the normality of the data was evaluated using the Shapiro-Wilk test ($\alpha = 0.05$). Where necessary, data were back-transformed and analyzed by ANOVA in a randomized complete block design, with potato cultivar treated as a sub-sample. A general linear model (GLM) with a binomial error structure was applied to account for the smaller variance in the scores of tolerant and susceptible cultivars (Freund et al., 2010). Treatment means were compared using Fisher's protected least significant difference (LSD) test at the 5% significance level.

**Results and Discussion**

**Morphological identification of potato seed tuber diseases**

Six fungal species were identified from 20 isolates obtained from atypical seed tuber blemishes collected in Lesotho, based on colony morphological and mycelial characteristics. The most frequently isolated species was *Rhizoctonia solani*, representing 33% of the isolates and recovered from both potato cultivars (Mondial and BP1). This was followed by *Fusarium* species, specifically *F. oxysporum* (16%) and *F. longifundum* (12%). Other pathogens identified included *Phytophthora infestans* (17%) and *Colletotrichum coccodes* (22%). Common saprophytes such as *Mucor* and *Rhizopus*, the potential biocontrol agent *Trichoderma*, and several yeast species were also part of the potato tuber mycobiota in Lesotho.

*P. infestans* cultures displayed two distinct growth patterns on PDA, both characterized by slow growth. Colonies were white to dull white with a rosette pattern. Microscopic examination revealed multinucleated, lemon-shaped, semi-papillate sporangia and aseptate mycelia (Figure 2), which are typical morphological features of *P. infestans* (Sobkowiak and Śliwka, 2017).

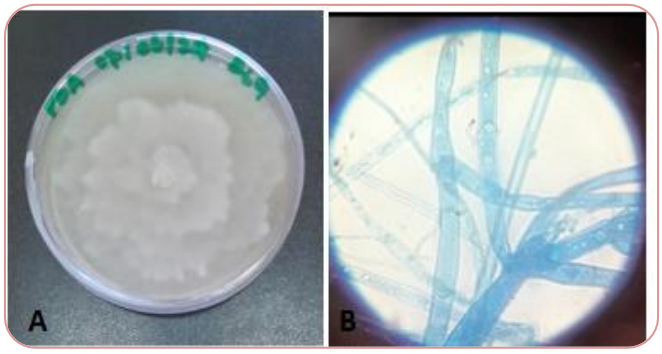


Figure 2. Mycelial growth of *P. infestans* on PDA medium: (A) white to dull-white colony with a rosette pattern; (B) microscopic view showing multinucleate, branched, and aseptate mycelia.

*R. solani* produced distinct colony colours and mycelial growth patterns on PDA, including white, cream, and light brown colonies, with sclerotia scattered across the surface. White colonies with cottony aerial mycelium were also observed (Figure 3).

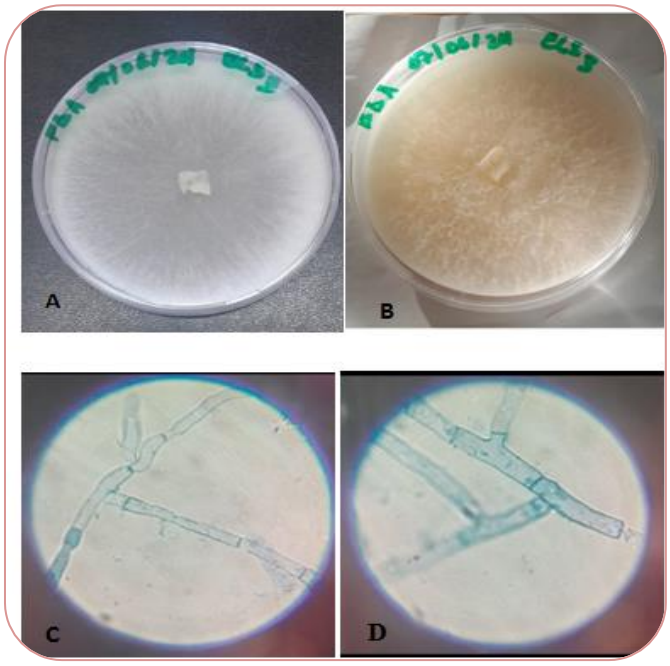


Figure 3. Microscopic view of *R. solani*: (A) white and cream colonies; (B) light brown colonies; (C) hyphal cell branching at a right angle; (D) hyphal cell branching at an acute angle with constrictions at the hyphal junction.

Under the microscope, *R. solani* isolates exhibited hyphal

cells with constrictions and branches arising from the main hypha at acute or right angles, with septa located near the branching points (Figure 3). These morphological features were consistent across all isolates and correspond to the representative characteristics of *R. solani*. Similar observations have been reported by Desvani et al. (2018) and Betancourth-Garcia et al. (2021), who described cream, light brown, and white colonies on culture media. In the present study, the hyphae displayed acute- and right-angled branching, with constrictions at the branch junctions and septa distal to the branch points (Figure 3). These results are in agreement with findings from Colombia and Lesotho reported by Betancourth-Garcia et al. (2021) and Mothebeli et al. (2023), respectively, which documented *R. solani* isolates exhibiting similar hyphal branching patterns and constrictions at the junctions.

The colony morphology of *Fusarium* exhibited distinct growth patterns, including adherent fluffy growth and smooth or flat forms. Colonies appeared whitish to pink, cottony, with dense, medium-growing mycelium and a dark-purple pigmentation on the reverse side of the medium (Figure 4). Microscopic observations revealed oval to kidney-shaped macroconidia with three septa, while the microconidia were oval or elliptical with a single septum. These results are consistent with the findings of Angel et al. (2016), who reported that *Fusarium* isolates produced oval and kidney-shaped macroconidia with three septa, and with Endriyas et al. (2020), who observed similar morphological characteristics.

Two isolates of C. coccodes grew rapidly on culture media, producing white colonies with circular margins that eventually turned grey as they matured on PDA (Figure 5). Several microsclerotia developed in the colony center, arranged in concentric rings, along with aseptate conidiomata, straight fusiform conidia, and unicellular conidia. These morphological characteristics were consistent with those described by Takooree et al. (2023).

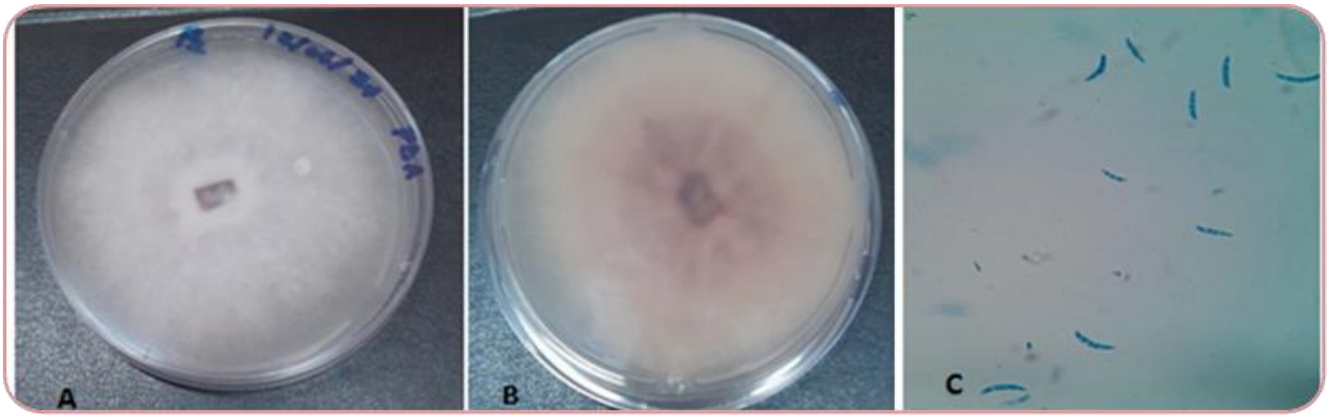


Figure 4. Mycelial growth of *F. oxysporum* on PDA medium: (A) colony with pink coloration, (B) colony with purplish coloration, and (C) microscopic characteristics showing macroconidia with 3-5 septa.

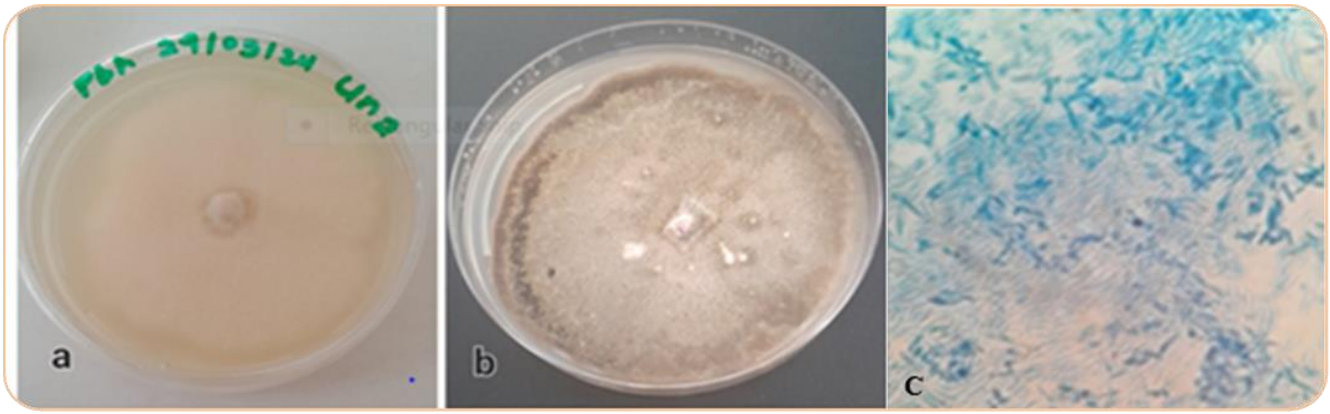


Figure 5. Mycelial growth of *C. coccodes*: (A) Pink colony with concentric rings; (B) Grey coloration in mature colonies; (C) Microscopic view showing aseptate conidiomata.

**Molecular characterization and phylogeny of three fungal species infecting potatoes**

Morphologically distinct fungal isolates were selected for phylogenetic analysis. Species identification was confirmed through BLASTn analysis of the ITS, *tef*-1α, and *rpb2* sequences against the NCBI GenBank database. All sequences exhibited 99-100% identity with reference strains in the database. Phylogenetic assignment, based on the highest sequence similarity matches, identified the isolates as *F. oxysporum*, *R. solani*, and *F. longifundum*. In the phylogenetic trees, the isolates clustered with their corresponding species from the GenBank database, supported by strong bootstrap values. Accession numbers for these isolates have been deposited in GenBank (Lekota et al., 2025a, b).

**Effect of seed health status on progeny tuber size distribution**

Seed health status had a highly significant effect on the size distribution and weight of progeny tubers in both trials, with no statistical differences ($P < 0.005$) between the trials for each treatment (Table 3; Figure 6). The use of symptomatic seed tubers produced the highest number of small-sized tubers, with a mean of 3.8 tubers per plant, which was significantly higher ($P < 0.005$) than the mean of 1 small tuber per plant obtained from asymptomatic (disease-free) seed tubers. The increased proportion of small tubers from symptomatic seed tubers is likely attributable to the higher incidence and severity of foliar diseases, which may have reduced plant vigor and altered assimilate partitioning.

These results align with the findings of Rahman and Akanda (2010), who reported that diseased plants generally perform poorly compared to healthy plants, producing smaller tubers due to disease pressure. Similarly, Van der Waals et al. (2001) observed that early blight infestation in potatoes significantly increased the proportion of small tubers and reduced overall yields in South Africa. *Alternaria* infestation, in particular, induces leaf necrosis and defoliation, which reduces the photosynthetic surface area, thereby limiting carbohydrate synthesis and translocation, ultimately decreasing tuber size and starch accumulation (Adolf et al., 2020).

The number of medium-sized tubers also differed significantly between treatments ($P < 0.005$). Disease-free seed tubers produced the highest mean number of medium-sized tubers (4 per plant) compared to symptomatic seed tubers (2.6 per plant). Likewise, the number of large-sized tubers was greatest in plants grown from disease-free seed tubers, with a mean of 4 per plant, whereas symptomatic seed tubers produced only 0.8 large tubers per plant.

These findings emphasize the importance of seed health and seed source in determining tuber yield and size distribution. Clean seed sourced from certified systems and free of visible disease symptoms produced significantly higher numbers of medium- and large-sized tubers compared to symptomatic seed tubers obtained from informal seed sources (Table 3; Figure 6). This is consistent with the results of Kigambo et al. (2023), who reported that certified seed yielded the highest number of medium-sized (2.79 t/ha) and large-sized tubers (3.59 t/ha), with a total tuber yield of 8.6 t/ha.

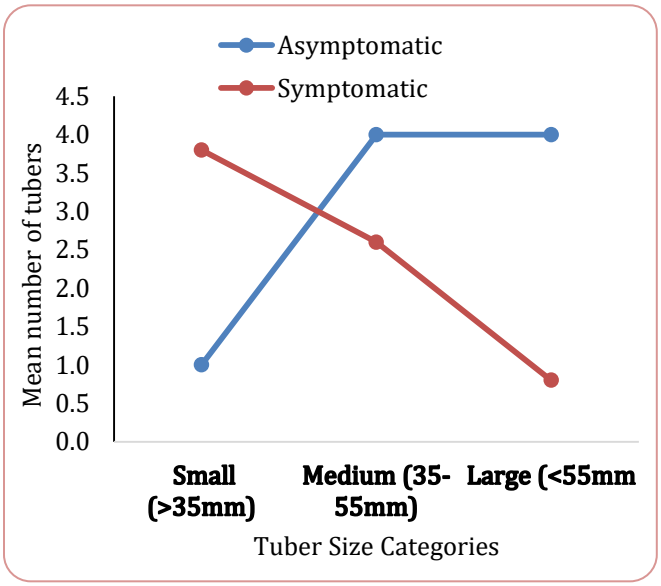


Figure 6. Effect of seed health on the size distribution of progeny tubers.

**Effect of seed health on progeny tuber weight**

The results showed statistically significant differences in total progeny tuber weight between symptomatic and asymptomatic seed tubers. Symptomatic seed tubers produced the lowest total tuber weight (123 g) (Table 3; Figure 7), which could be attributed to the high severity of pathogen inoculum on the seed tubers. In contrast, asymptomatic seed tubers yielded a higher mean tuber weight (204.5 g) of healthy tubers that showed no disease symptoms. These findings are consistent with those of Huda (2021), who reported that certified clean seed produced the maximum tuber weight, whereas farmer-saved seed produced the minimum. Similarly, Rahman and Akanda (2010) found that seed tubers infected with

Potato Leafroll Virus (PLRV) at varying levels caused substantial reductions in both the number and weight of tubers, with the degree of reduction correlating with the severity of the inoculum. Likewise, Daami-Remadi et al. (2008) reported that planting seed tubers heavily infested with *R. solani* significantly reduced the fresh weight of progeny tubers.

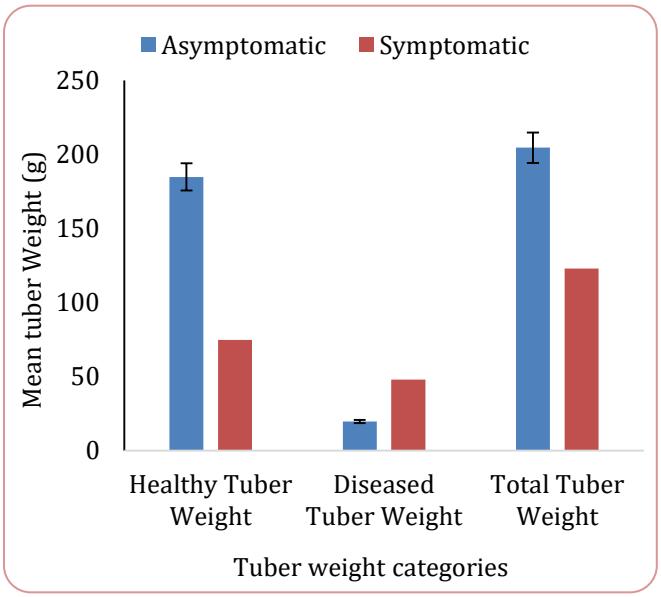


Figure 7. Effect of seed health status on the weight of progeny tubers.

**Effect of seed health status on the total number of progeny tubers**

The total number of tubers per potato plant was significantly influenced by seed health status ($P < 0.005$). Plants grown from asymptomatic seed tubers produced the highest number of tubers per plant (9.6), which was significantly greater than that of plants grown from symptomatic seed tubers (7.2) (Table 3; Figure 8). This finding indicates that certified, disease-free seed tubers promote greater tuber production, potentially due to a lower pathogen inoculum load compared to symptomatic seed tubers sourced from informal seed systems. These results are consistent with the findings of Huda et al. (2021), who reported the highest tuber number per plant (8.3) from certified disease-free seed, whereas the lowest (6.0) was recorded from progeny tubers derived from farmers' own seed potatoes. Similarly, Kigambo et al. (2021) found that healthy, disease-free seed obtained from formal sources yielded a higher total tuber number (8.6) compared to seed from local markets, which produced only 7.0 tubers per plant. Furthermore, Wang (2008) demonstrated a 28.4% yield difference between high-quality and poor-quality seed, reinforcing the role of seed health in productivity. Poor-quality seed often harbors important potato seed-borne pathogens (Schulte-Geldermann et al., 2013).

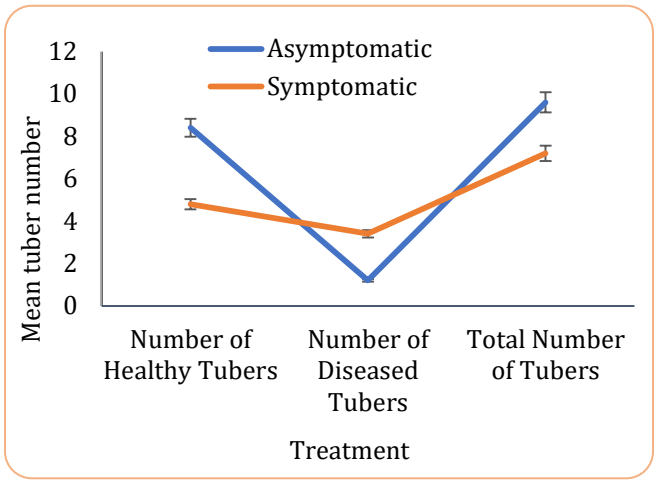


Figure 8. Effect of seed health status on the mean number of tubers per plant.

**Impact of potato seed health status on disease incidence and severity of progeny tubers**

Analysis of variance from the first trial revealed a highly significant difference ($P < 0.005$) in disease incidence and severity for different identified diseases between plants grown from symptomatic and asymptomatic seed tubers (Table 3; Figure 9). Overall, symptomatic seed tubers exhibited the highest mean disease incidence (47.6%) and severity (35%), whereas asymptomatic seed tubers showed substantially lower values, with a mean disease incidence of 11.8% and severity of 10.6% (Figure 10). These findings demonstrate that the use of clean, certified seed tubers significantly reduces disease incidence and severity, likely due to higher genetic resistance and the absence of seed-borne pathogens.

Similarly, Awadalla et al. (2017) reported that planting infected seed tubers resulted in the greatest overall mean disease incidence and severity, whereas planting clean potato seed produced progeny tubers free from disease symptoms. Kamuyu et al. (2017) also found a significant negative correlation between the use of clean seed and disease prevalence, with disease incidence decreasing as the use of clean seed increased. Their results suggest that seed-borne inoculum plays a key role in contaminating soil, leading to subsequent infection of healthy potato stocks. Comparable findings

by Topp et al. (2019) showed higher mean disease incidence in crops grown from farm-saved seed than from commercially certified seed. These results highlight that high disease incidence and severity of major potato diseases often occur due to limited access to clean seed tubers. Nevertheless, selecting and using clean planting material can substantially reduce these problems (Muhinyuza, 2014). However, Kinyua et al. (2001) noted that bacterial wilt outbreaks occurred in some farms even when certified, disease-free tubers were planted.

Table 3. Mean values showing the effect of potato seed health on yield, disease incidence and disease severity index of progeny tubers.

| Variable | Trial 1 | | | Trial 2 | | | Average means | |
|---|---|---|---|---|---|---|---|---|
| | Symptomatic | Asymptomatic | LSD | Symptomatic | Asymptomatic | LSD | Symptomatic | Asymptomatic |
| Tuber size | | | | | | | | |
| Small (>35 mm) | 4.6[a] | 1.0[b] | 1.1 | 3.0[a] | 1.0[b] | 1.0 | 3.8[a] | 1.0[b] |
| Medium (35-55mm) | 2.1[b] | 4.1[a] | 1.2 | 3.1[a] | 3.9[a] | 1.3 | 2.6[b] | 4.0[a] |
| Large (<55 mm) | 0.4[b] | 4.5[a] | 2.6 | 1.2[b] | 3.5[a] | 12.0 | 0.8[b] | 4.0[a] |
| Total tuber number | 6.4[a] | 7.0[a] | 2.1 | 7.2[b] | 9.8[a] | 2.3 | 6.8[b] | 8.4[a] |
| Total tuber weight (g) | 116.2[b] | 224.2[a] | 48.9 | 129.8[b] | 184.8[a] | 30.8 | 123[b] | 204.5[a] |
| DI | 30.2[a] | 7.6[b] | 18.1 | 65[a] | 16[b] | 23 | 47.6[a] | 11.8[b] |
| DSI | 34[a] | 7.1[b] | 22.9 | 36[a] | 14.1[b] | 17 | 35[a] | 10.6[b] |

Means with different letters within the same column are significantly different ($p < 0.05$). Means represent the average of five replications per treatment.

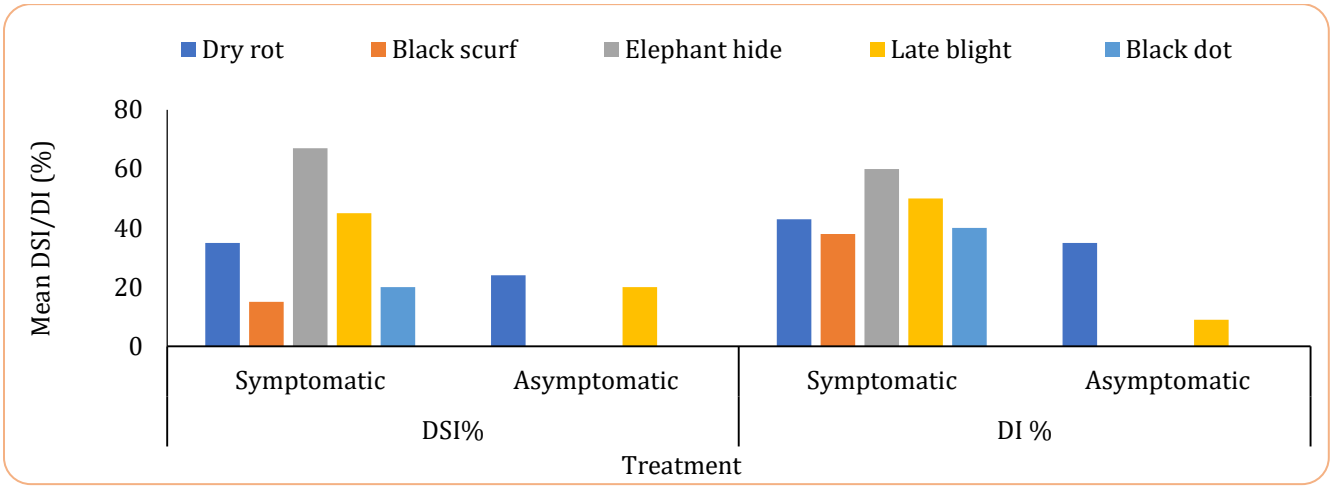


Figure 9. Average percentage disease severity index (DSI) and Disease incidence (DI) of different diseases in symptomatic and asymptomatic treatments.

Five diseases were predominantly identified from visual assessments of progeny potato tubers: dry rot (*F. oxysporum*), late blight (*P. infestans*), black dot (*C. coccodes*), black scurf (*R. solani*), and elephant hide (*R. solani*). Dry rot incidence (43%) and severity (35%) were higher in the symptomatic seed treatment compared to the asymptomatic seed treatment (35% incidence and 24% severity). Dry rot symptoms are often difficult to detect on seed tubers because decay is typically internal. Spores attached to seed tubers may serve as a source of inoculum, although the pathogen is primarily soil-borne (Tiwari et al., 2020). Although dry rot is mainly a post-harvest disease affecting stored tubers (Tein, 2015), it can also affect seed tubers after

planting. Interestingly, the relatively low incidence and severity of dry rot in symptomatic treatments compared with asymptomatic certified seed suggests that latent infections can occur in certified seed lots. Ray et al. (2024) demonstrated that volatile organic compounds (VOCs) can be used as biomarkers for early detection of dry rot in symptomless potato tubers.

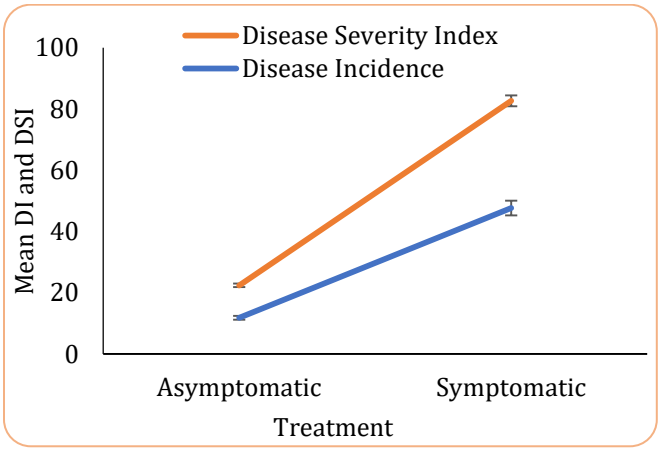


Figure 10. Effect of seed health on mean disease incidence and disease severity index.

Late blight incidence (50%) and severity (45%) were highest in the symptomatic seed treatment, whereas the asymptomatic seed treatment recorded much lower values (9% incidence and 20% severity). These results emphasize the importance of seed certification in late blight management, as certified seeds showed greater tolerance to *P. infestans*, likely due to genetic purity. However, the presence of low incidence and severity in certified seed implies the possibility of latent infections. Powelson et al. (2002) reported that up to 20% of tubers can be infected with *P. infestans* without showing visible symptoms. Planting infected seed tubers can lead to poor germination or symptomatic plants, as infected tubers serve as a major source of inoculum.Black dot incidence was 40% with 20% severity in symptomatic seed treatments, whereas asymptomatic seed tubers produced progeny tubers without visible black dot symptoms. The higher black dot levels in symptomatic treatments may be linked to weakened plant immunity and seed-borne inoculum. Similar results were reported in studies associating black dot with abiotic stress and co-infection with *P. infestans* (El-Fawy et al., 2023; Kuznetsova et al., 2024). Conversely, Sanzo-Miró et al. (2023) found that while black dot is seed-borne, seed inoculum does not significantly influence disease severity in progeny tubers. Massana-Codina et al. (2021) also observed no direct relationship between black dot incidence in seed tubers and disease severity in progeny. Generally, infected seed tubers and contaminated soil are the main sources of *C. coccodes* inoculum, with symptoms developing mainly at crop senescence. Early harvesting of susceptible cultivars can reduce black dot symptoms (Danaher and Hilton, 2005).

Elephant hide incidence (60%) and severity (67%), both caused by *R. solani*, were recorded in symptomatic seed treatments, whereas no symptoms were observed in progeny tubers from asymptomatic seed. Similarly, black scurf incidence (38%) and severity (15%) were recorded in symptomatic seed treatments, but absent in asymptomatic treatments. These results indicate a high level of tolerance in certified seed against *R. solani*. Fankhauser (2000) reported significantly lower *R. solani* sclerotia in tubers harvested from clean seed compared to symptomatic seed, confirming the major role of seed-borne inoculum in yield and quality reduction. Navarrete et al. (2017) also found black scurf in 80.5% of sampled tubers, with incidence strongly influenced by seed health and quality, although severity was generally low.

## Conclusion

The findings of this study demonstrate that potato seed health has a significant influence on yield, yield components, and tuber quality. Parameters such as tuber weight, size, number, disease incidence, and disease severity in progeny plants and tubers were strongly affected by the health status of the seed. Healthy, symptom-free seed tubers consistently produced higher yields and better-quality tubers, characterized by larger sizes, greater numbers, and higher weights. Furthermore, the use of healthy seeds was associated with markedly lower disease incidence and severity, confirming the pivotal role of seed health in potato disease management and overall production efficiency. The results clearly indicate that the use of high-quality, certified, disease-free seed tubers contribute to improved yields and superior tuber quality.

## Recommendations

Based on these findings, it is recommended that potato farmers in Lesotho prioritize the use of high-quality, disease-free seed tubers in their cultivation practices. This can be achieved by obtaining certified potato seed with an official certification tag from registered and

accredited seed sources that follow strict quality control protocols, as certified seed undergoes rigorous testing to ensure it is free from pathogens and is often selectively bred for disease resistance, thereby reducing the risk of introducing diseases into the field. Seed stocks should be regularly tested, and both internal and external quarantine measures should be enforced to prevent the introduction and spread of potato diseases within the country. In addition, seed tubers should be treated with appropriate fungicides or bactericides before planting to further minimize the risk of infection. Farmers should also be trained and made aware of the critical role of seed health in disease management and yield improvement, enabling them to adopt better seed selection, handling, and storage practices. The implementation of these measures will help reduce disease pressure, improve yields, and enhance the overall quality of potato production in Lesotho.

**Acknowledgements**

The authors express their gratitude to the National University of Lesotho (NUL) for providing the opportunity to undertake this study and to the National Manpower Development Secretariat (NMDS), Lesotho, for the student support.

**Authors' Contributions**

ML and KN designed the study; KN prepared the materials, collected and analyzed the data; SM helped in disease scoring. ML and NM supervised the studies; KN, ML and NM wrote the manuscript; All the authors proofread and approved the final manuscript.

**Research Funding**

This research did not receive any grant from funding agencies.

**Conflict of Interest**

The authors declare no conflict of interest.

**Sustainable Development Goals Targeted**

SDG 2: Zero Hunger
SDG 9: Industry, Innovation, and Infrastructure
SDG 12: Responsible Consumption and Production

**References**

Adane, H.T., 2013. Economic and agronomic analysis of the seed potato supply chain in Ethiopia. PhD Thesis. Agricultural Economics, Wageningen University, Wageningen NL. BN: 978-94-6173-543-0.

Adolf, B., Andrade-Piedra, J.L., Molina, F., Przetakiewicz, J., Hausladen, H., Kromann, P., Lees, A.K., Lindqvist-Kreuze, H., Perez, W., Secor, G.A., 2020. Fungal, oomycete, and plasmodiophorid diseases of potato. In: Campos, H., Ortiz, O. (eds), The potato crop. Springer, Cham.

Ahmad, I., Soomro, M.H., Khalid, S., Iftikhar, S., Munir, A., Burney, K., 1995. Recent distributional trends of potato diseases in Pakistan. National Seminar on Research and Development of Potato Production in Pakistan, Islamabad, Pakistan.

Angel, R.C., Michel, L.M., Lidcay, H.I., Aminael, S.-R., Roldán, T.G., 2016. Morphological and molecular identification of *Fusarium* species associated with vascular wilt of babaco (*Vasconcellea heilbornii* var. *pentagona* Badillo). Revista de Protección Vegetal 31, 184-193.

Awadalla, I.A.I., Irabi, M., Mohamed, Y.A.A., Elhassan, S.M., 2017. Role of infected seed potato tuber in contamination of land and clean potato stocks with common scab. Journal of Advances in Biology & Biotechnology 12, 1-8.

Betancourth-Garcia, C.A., Castro-Caicedo, B.L., Quiroz-Ojeda, C., Sanudo-Sotelo, B., Florence-Casanova, C., Salazar-Gonzalez, C., 2021. Morphology and pathogenicity of *Rhizoctonia solani* Kuhn associated with potato black scurf in Narino (Colombia). Revista Colombiana de Ciencias Hortícolas 5, 11821.

Bindu, M.G., Devi, G.U., Kumar, V.K., Babu, R.T., Naidu, T.C.M., 2017. Cultural and morphological characterization of *Rhizoctonia solani* f. sp. *sasakii* isolates collected from different districts of Andhra Pradesh. International Journal of Current Microbiology and Applied Sciences 6, 3457-3469.

Daami-Remadi, M., Zammouri, S., Mahjoub, E.I.M., 2008. Effect of the level of seed tuber infection by *Rhizoctonia solani* at planting on potato growth and disease severity. The African Journal of Plant Science and Biotechnology 2, 34-38.

Danaher, J., Hilton, A., 2005. Prediction and manipulation of black dot development in potato crops. British Potato Council, Oxford Business Park South, Oxford.

Dennis, A.J., Brad, G., Leah, L.T., 2018. Potato black dot-the elusive pathogen, disease development and management. American Journal of Potato Research

95, 340-350.

Darriba, D., Taboada, G.L., Doallo, R., Posada, D. 2012. jModelTest 2: more models, new heuristics and parallel computing. Nature Methods 9(8), 772. doi: 10.1038/nmeth.2109.

Desvani, S., Lestari, I., Wibowo, R., Supyani, S., Poromarto, S., Hadiwiyono, H., 2018. Morphological characteristics and virulence of *Rhizoctonia solani* isolates collected from some rice production areas in some districts of Central Java. AIP Conference Proceedings 2014, 020068.

El-Fawy, M.M., Abo-Elyousr, K.A.M., Sallam, N.M.A., El-Sharkawy, R.M.I., Ibrahim, Y.E., 2023. Fungicidal effect of guava wood vinegar against *Colletotrichum coccodes* causing black dot disease of potatoes. Horticulturae 9, 710.

Endriyas, G., Daniel, T., Getachew, A., 2020. Cultural, morphological and pathogenic variability among isolates of *Fusarium oxysporum* f. sp. *capsici* causing wilt of hot pepper in Central Rift Valley, Ethiopia. Journal of Plant Pathology & Microbiology 11, 1-12.

Fankhauser, C., 2000. Seed-transmitted diseases as constraints for potato production in the tropical highlands of Ecuador. PhD thesis, Swiss Federal Institute of Technology Zurich.

Freund, R.J., Wilson, W.J., Mohr, D.L., 2010. Linear regression. In Statistical Methods (3rd ed., pp. 321-374.

Gildemacher, P.R., Mwangi, J., Demo, P., Barker, I., 2007. Prevalence of potato viruses in Kenya and consequences for seed potato system research and development. In: Proceedings of the 7th Triennial African Potato Association Conference, Alexandria, Egypt, pp. 84-92.

Gildemacher, P.R., Schulte-Geldermann, E., Borus, D., Demo, P., Kinyae, P., Mundia, P., Struik, P.C., 2011. Seed potato quality improvement through positive selection by smallholder farmers in Kenya. Potato Research 54, 253-266.

Guindon, S., Gascuel, O., 2003. A simple, fast, and accurate algorithm to estimate large phylogenies by maximum likelihood. Systematic Biology 52, 696-704.

Gush, S., Muzhinji, N., Truter, M., Van der Waals, J.E., 2019. First report of *Rhizoctonia solani* AG 2-2IIIB causing elephant hide on potato tubers in South Africa. Plant Disease 103, 1850.

Hall, T.A., 1999. BioEdit: A user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. Nucleic Acids Symposium Series 41, 95-98.

Hlaiem, S., Della, R.G., Barberini, S., Danti, R., Lahbib, J.B.M., 2021. Morphological and molecular identification of *Fusarium oxysporum* f. sp. l*ycopersici* associated with *Olea europaea* var. *sylvestris* decline phenomenon in Tunisia. Plant Pathology & Quarantine 11, 15-22.

Huda, M.S., Hossain, S.M.M., Islam, M.R., Islam, A.T.M.S., Hannan, A., 2021. Quality assessment of the farmer's produced seed potatoes. Bangladesh Journal of Agricultural Research 46, 343-352.

Jean, R., Gail, L.S., Cleora, J.D., 2018. Late blight of potato and tomato. The Plant Health Instructor.

Kamuyu, L.M., Muiru, W.M., Kimenju, J.W., Nyongesa, M.W., 2017. Potato seed production systems and disease prevalence in major potato growing regions in Kenya. International Journal of Current Microbiology and Applied Sciences 6, 1012-1020.

Kigambo, M., Wasswa, P., Nakibuule, J., Kajunju, N.H.B., Obala, J., Mugisha, J., 2021. Effect of seed size and fungicidal protection of potato seed from different sources on growth and tuber yield in Uganda. RUFORUM Working Document Series 19, 163-169.

Kigambo, M., Wasswa, P., Obala, J., Nakibuule, J., Mugisha, J., 2023. Effect of seed source, size and treatment on potato growth and yield. Makerere University Journal of Agricultural and Environmental Sciences 12, 1-22.

Kiliçoğlu, M.Ç., Özköç, İ., 2013. Phylogenetic analysis of *Rhizoctonia solani* AG-4 isolates from common beans in Black Sea coastal region, Turkey, based on ITS-5.8S rDNA. Turkish Journal of Biology 37, 18-24.

Kim, N.S., Hong, S.J., Won, H.S., Kim, B.S., Gwon, S.H., 2023. Identification and pathogenicity of species isolated from stored potato tubers showing symptoms of dry rot disease. Potato Research, 67(4), 1797-1808.

Kinyua, Z.M., Smith, J.J., Lung'aho, C., Olanya, M., Priou, S., 2001. On-farm successes and challenges of producing bacterial wilt-free tubers in seed plots in Kenya. African Crop Science Journal 9, 279-285.

Kuznetsova, M.A., Statsyuk, N.V., Demidova, V.N., Semeniuk, I.N., Smetanina, T.I., Ukolova, A.Y., Vyatchinov, A.A., 2024. A complex approach to control black dot disease in potato. Agronomy 14, 1373.

Lal, M., Sharma, S., Yadav, S., Kumar, S., 2018. Management of late blight of potato. Potato-from Incas to all over the world. InTech. DOI: 10.5772/intechopen.72472.

Lekota, M., Machela, S., Nketsi, K., Muzhinji, M., 2025. First report of *Fusarium oxysporum* and *F. longifundum* causing dry rot of potato *(Solanum tuberosum* L.) in Lesotho. Manuscript under review.

Lekota, M., Nketsi, K., Machela, S., Muzhinji, M., 2025. *Rhizoctonia solani* AG4 HG-I causing black scurf of potato (*Solanum tuberosum* L.) tubers in Lesotho. Manuscript under review.

Martín, I., Gálvez, L., Guasch, L., Palmero, D., 2022. Fungal pathogens and seed storage in the dry state. Plants 11(22), 3167.

Massana-Codina, J., Schnee, S., Lecoultre, N., Droz, E., Dupuis, B., Keiser, A., de Werra, P., Wolfender, J.L., Gindro, K., Schürch, S., 2021. Influence of abiotic factors, inoculum source, and cultivar susceptibility on the potato tuber blemish diseases black dot (*Colletotrichum coccodes*) and silver scurf (*Helminthosporium solani*). Plant Pathology 70(4), 885-897.

Mekonnen, G., 2020. Review on: Impact of seed-borne pathogens on seed quality. American Journal of Plant Biology 5(4), 77-81.

Molahlehi, L., Steyn, J.M., Haverkort, A.J., 2013. Potato crop response to genotype and environment in a subtropical highland agro-ecology. European Potato Journal 56(3).

Mothibeli, K., Lekota, M., Liphoto, M., Morojele, M.E., Muzhinji, N., 2023. First report of *Rhizoctonia solani* associated with black scurf of potato tubers in Lesotho. International Journal of Phytopathology 12(1), 87-97.

Muhinyuza, J.B., 2014. Breeding potato (*Solanum tuberosum* L.) for high yield and resistance to late blight in Rwanda. PhD thesis. University of KwaZulu-Natal, Republic of South Africa.

Muzhinji, N., Woodhall, J.W., Truter, M., Van der Waals, J.E., 2014. Elephant hide and growth cracking on potato tubers caused by *Rhizoctonia solani* AG3-PT in South Africa. Plant Disease 98(4), 570.

Navarrete, I., Panchi, N., Kromann, P., Forbes, G.A., Andrade-Piedra, J.L., 2017. Health quality of seed potato and yield losses in Ecuador. BioRxiv 108712.

O'Donnell, K., Whitaker, B.K., Laraba, I., Proctor, R.H., Brown, D.W., Broders, K., Kim, H.S., McCormick, S.P., Busman, M., Aoki, T., Torres-Cruz, T.J., Geiser, D.M., 2022. DNA sequence-based identification of *Fusarium*: A work in progress. Plant Disease 106(6), 1597-1609.

Powelson, M.L., Ludy, R., Partipilo, H., Inglis, D.A., Gundersen, B., Derie, M., 2002. Seed borne late blight of potato. Plant Health Progress 3(1), 10.1094/PHP-2002-0129-01-HM.

Rahman, M.S., Akanda, A.M., 2010. Effect of PLRV infected seed tuber on disease incidence, plant growth and yield parameters of potato. Bangladesh Journal of Agricultural Research 35(3), 359-366.

Rakibuzzaman, M.A., Siddika, M.H., Uddin, A.F.M.J., 2021. Impact of *Trichoderma* application as bio-stimulator on disease suppression, growth and yield of potato. Journal of Bioscience and Agriculture Research 27(1), 2252-2257.

Ray, R., Singh, S.S., Yadav, S.R., Sircar, D.A., 2024. A nondestructive asymptomatic early disease prediction method employing ROS-induced differential volatile emissions from dry rot-infected potatoes. Plant Physiology and Biochemistry 208, 108532.

Sanzo-Miró, M., Simms, D.M., Rezwan, F.I., Terry, L.A., Alamar, M.C., 2023. An integrated approach to control and manage potato black dot disease: A review. American Journal of Potato Research 100, 362-370.

Schulte-Geldermann, E., Wachira, G., Ochieng, B., Barker, I., 2013. Effect of field multiplication generation on seed potato quality in Kenya. In: Woldegiorgis, G., Schulz, S., and Berihun, B. (eds.), Seed potato tuber production and dissemination, experiences, challenges and prospects: Proceedings, Bahir Dar, Ethiopia, pp. 81-90.

Sobkowiak, S., and Śliwka, J., 2017. *Phytophthora infestans*: Isolation of pure cultures, storage and inoculum preparation. Plant Breeding and Seed Science 76(1), 9-15.

Swofford, D. L., 2002. PAUP*. Phylogenetic analysis using parsimony and other methods. Version 4.0b10. Evolution Version 4.0. DOI: 10.1111/j.0014-3820.2002.tb00191.x.

Takooree, S.D., Neetoo, H., Ranghoo-Sanmukhiya, V.M., 2023. First report of *Colletotrichum coccodes* causing black dot on potato in Mauritius. New Disease Reports 48, e12224.

Tein, B., 2015. The effect of different farming systems on potato tuber yield and quality. PhD thesis. The Estonian University of Life Sciences.

Thomas-Sharma, S., Abdunahman, A., Ali, S., Anndrade-Piedra, J.L., Bao, O., Kroman, P., Struik, P.C., Torrence, L., Garrett, K.A., Forbes, G.A., 2015. Seed degeneration in potato: The need for integrated seed health strategy to mitigate the problem in developing countries. Plant Pathology 65, 3-16.

Tiwari, R.K., Kumar, R., Sharma, S., Sagar, V., Aggarwal, R., Naga, K.C., Lal, M.K., Chourasia, K.N., Kumar, D., Kumar, M., 2020. Potato dry rot disease: Current status, pathogenomics and management. 3 Biotechnology 10(11), 503.

Topp, C.F.E., Hughes, G., Nevison, I.M., Butler, A., Oxley, S.J.P., Havis, N.D., 2019. *Rhynchosporium* leaf scald disease incidence: Seed source and spatial pattern. Plant Pathology 68, 1179-1187.

Tsedaley, B., 2014. Late blight of potato *(Phytophthora infestans*) biology, economic importance and its management approaches. Journal of Biology, Agriculture and Healthcare 4(25), 215-225.

Tsegaye, B., Dechassa, N., Mohammed, W., 2019. Physical quality characteristics of potato (*Solanum tuberosum* L.) tubers as influenced by cultivar and plant spacing in Eastern Ethiopia. International Journal of African and Asian Studies 52, 2409-6938.

Tuquerrez, G.K.C., Pavon, G.A.N., Moya, J.C.E., Park, C.H., 2023. Effect of use of certified seed to increase potato (*Solanum tuberosum*) production in Ecuador. Ciencia Latin Internacional 7(5), 8310-8326.

Uthayasooriyan, M., Pathmanathan, S., Ravimannan, N., Sathyaruban, S., 2016. Formulation of alternative culture media for bacterial and fungal growth. 8, 444-449.

Van der Waals, J.E., Korsten, L., Aveling, T.A.S., 2001. A review of early blight of potatoes. African Plant Protection 7(2), 91-102.

Wang, F., 2008. The importance of quality potato seed in increasing potato production in Asia and the Pacific region. Food and Agriculture Organization of the United Nations, Asia, Bangkok, Thailand. https://www.fao.org/4/i0200e/I0200E10.htm. Accessed December 2024.

Wharton, P., Kirk, W., 2007. Potato diseases: Potato seed piece health management. Department of Plant Pathology, Michigan State University, Michigan. Extension Bulletin E-2995.

White, T.J., Bruns, T.D., Lee, S.B., Taylor, J.W., 1990. Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In: PCR protocols, a guide to methods and applications, 315-322.

Xue, H., Liu, Q., Yang, Z., 2023. Pathogenicity, mycotoxin production, and control of potato dry rot caused by *Fusarium* spp.: A review. Journal of Fungi (Basel, Switzerland) 9(8), 843.

Zhang, M., Shi, Z., Chen, G., Cao, A., Wang, Q., Yan, D., Fang, W., Li, Y., 2023. Detection and identification methods and control techniques for crop seed diseases. Agriculture 13, 1786.

Zimudzi, J., Coutinho, T., Smith, J., 2017. Pathogenicity of fungi isolated from atypical skin blemishes on potatoes in South Africa and Zimbabwe. Potato Research 60, 1-26.