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Understanding farmer knowledge, practices and decision-making in pest and disease management: the case of Irish potato (*Solanum tuberosum*) cultivation in Mbeya, Tanzania

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Abstract

Irish potato (*Solanum tuberosum*) is an important food and cash crop for smallholder farmers in Tanzania, particularly in the Southern Highlands. Despite these, yields remain low due to persistent challenges from pests and diseases, threatening both productivity and household incomes. This study examined knowledge, perceptions and practices of smallholder farmers in managing pests and diseases of Irish potato in Mbeya, Tanzania. A total of 225 farmers from five wards were surveyed using structured interviews and focus group discussions. Most respondents (83%) identified pests and 73% identified diseases as major constraints. Aphids (83%), whiteflies (71%) and potato tuber moth (39%) were the most commonly reported pests, while early blight (91%), late blight (45%) and Fusarium wilt (29%) were the most cited diseases. Despite the widespread use of chemical pesticides (92%) and fungicides (72%), access to these inputs was constrained by high costs, limited availability and insufficient knowledge, with only 24% of farmers reporting effective use. Non-chemical methods, such as crop rotation, intercropping and botanical extracts, were rarely practiced, reflecting low awareness and limited extension support. Most farmers relied on experience rather than consulting agricultural officers, and over 90% used traditional seed varieties. Yields varied significantly among wards, with averages ranging from 1.1 to 22.4 t/ha. While farmers demonstrated awareness of pests and diseases, management practices were heavily dependent on synthetic chemicals, with minimal integration of sustainable strategies. These findings highlight the need to promote integrated pest and disease management approaches tailored to local conditions for improving productivity of Irish potato.

Keywords Smallholder farmer, Solanum tuberosum, Crop protection, Sustainable agriculture, Integrated pest and disease management

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1 Introduction

Irish potato (*Solanum tuberosum*) ranks as the third most important food crop globally after rice and wheat, with an estimated annual global production of over 375 million tonnes [1]. The crop is cultivated across a wide range of agro-ecological zones, from the temperate fields of Europe to the highlands of Africa and Asia [2]. Globally, Irish potato production is valued at over USD 120 billion annually, with China being the biggest producer with an estimated 95.5 million tonnes, followed by India (56 million tonnes) and Ukraine (20.9 million tonnes) [3, 4]. In Africa, potato production is expanding rapidly as both a food and cash crop, with Egypt leading with annual production of about 6.2 million tonnes, followed by Algeria (4.3 million tonnes) and South Africa (2.5 million tonnes) [5–7]. In regions with mechanization, certified seed systems and integrated pest management, yields frequently exceed 40 t/ha [8, 9]. In contrast, yields in most African countries is below international standards ranging from 8 to 15 t/ha despite the favorable growing conditions, reflecting dependence on traditional seeds, high input costs and limited access to extension services [10–12].

In Tanzania, Irish potato is predominantly cultivated in high-altitude zones such as the Southern Highlands, where cooler temperatures and reliable rainfall create favorable conditions for production [13, 14]. The crop plays a dual role as both food and a source of income, contributing significantly to household economy, rural livelihood and national economy, with annual revenues estimated at over USD 254 million through domestic consumption, local markets and limited exports [15–17]. Despite its importance, productivity remains low, averaging 6–12 t/ha which mirrors production challenges faced across much of sub-Saharan Africa [18, 19]. These challenges translate into significant income losses, highlighting the urgent need for interventions that enhance access to improved seed, promote sustainable crop protection measures and strengthen advisory services [20, 21].

Insect pests and diseases are among the major constraints of Irish potato production in most parts of Tanzania including Mbeya region [22]. Studies have shown that the severity of insect pests and diseases damage in Irish potato production in smallholder farming systems is significant, emphasizing the need for developing more effective and affordable means of managing and controlling them [23]. The most important insect pests in Irish potato farming are cutworm (*Peridroma saucia*), which attacks the stem near or at the soil surface, and potato tuber moth (*Phthorimaea operculella*), which attacks potato tubers both in the field and in storage [24]. Diseases, on the other hand, have also been reported to significantly reduce harvest, and the most problematic are fungal diseases including early blight and late blight caused by *Alternaria solani* and *Phytophthora infestans*, respectively [25, 26]. The dynamics of pests and diseases due to changes in weather conditions have made it very difficult for smallholder farmers to sustainably manage and control them [27].

The application of pesticides has been reported as the primary strategy for managing and controlling pests and diseases in Irish potato farming [24, 28]. Due to increased incidents of pests and diseases attacks, farmers have responded by applying more insecticides and fungicides [29, 30]. This surge in pesticides raises safety concerns particularly to the consumers and the environment at large [31–33]. While pesticides application remain an important tool for managing pests and diseases in Irish potato production, their use alone is not sufficient [34, 35]. Challenges such as high costs, limited

accessibility, improper application and concerns over human health, environmental contamination and pesticide resistance highlight the need for complementary and sustainable approaches [36–38]. This emphasizes the need for exploring and developing other strategies, along with integrated pest and disease management (IPDM), however, the farmers' knowledge, perception, and practices in managing pests and diseases should be fully realized and incorporated in the process [38–40].

Previous research conducted in Tanzania and other East African countries has predominantly focused on production constraints, varietal improvement and seed systems, with little attention given to the methods by which farmers identify pests and diseases, evaluate their severity and select control measures [10, 41]. This lack of understanding has led to inconsistent adoption of sustainable management practices and an overdependence on chemical control, thereby increasing the risk of pest resistance, health hazards and environmental degradation [42–44]. There is therefore a need to explore how smallholder farmers perceive and manage pests and diseases in Irish potato production to provide evidence that informs the development of IPDM approaches tailored to local conditions [45].

This study was conducted to address the limited understanding of how smallholder farmers in Mbeya perceive and manage pests and diseases in Irish potato production. The objective was to generate evidence that could inform the development of IPDM approaches compatible with existing practices, such as the use of traditional seed and routine pesticide application. By doing so, the new IPDM approaches can be presented as enhancements rather than replacements, thereby improving their adoption and long-term sustainability. Specifically, the study aimed to: (i) assess farmers' knowledge and perceptions of pests and diseases, focusing on their understanding of causes, symptoms, and impacts on production; (ii) examine the practices currently employed to manage these constraints, including both traditional and chemical-based methods; and (iii) identify the main challenges farmers encounter in pest and disease management, along with potential areas for targeted interventions.

2 Materials and methods

2.1 Study site

The survey was conducted between June and August 2024 across 12 villages in 5 wards (Igoma, Uyole, Utengule, Iwambi, and Iyunga) within Mbeya Urban and Mbeya Rural districts (Fig. 1). These wards were identified as the key Irish potato producing zones through consultations with Agricultural Officers in Mbeya, who provided expert guidance based on production records and knowledge of farming practices. The areas selected represent the most significant contributors to potato output in the Southern Highlands, a region that accounts for an estimated 70–80% of the country's total production [46]. Climatically, the study area experiences a bi-modal rainfall pattern, with annual precipitation ranging from 800 to 1200 mm. The long rains occur between March and May, while the short rains fall from October to December. Average annual temperatures range from 15 to 25 °C, with cooler conditions at higher elevations and warmer conditions in the lowlands. These favorable conditions such as ample rainfall, moderate temperatures, and fertile soils make Mbeya one of the most important agricultural hubs in Tanzania. This also highlights the relevance of situating the study in this region, where

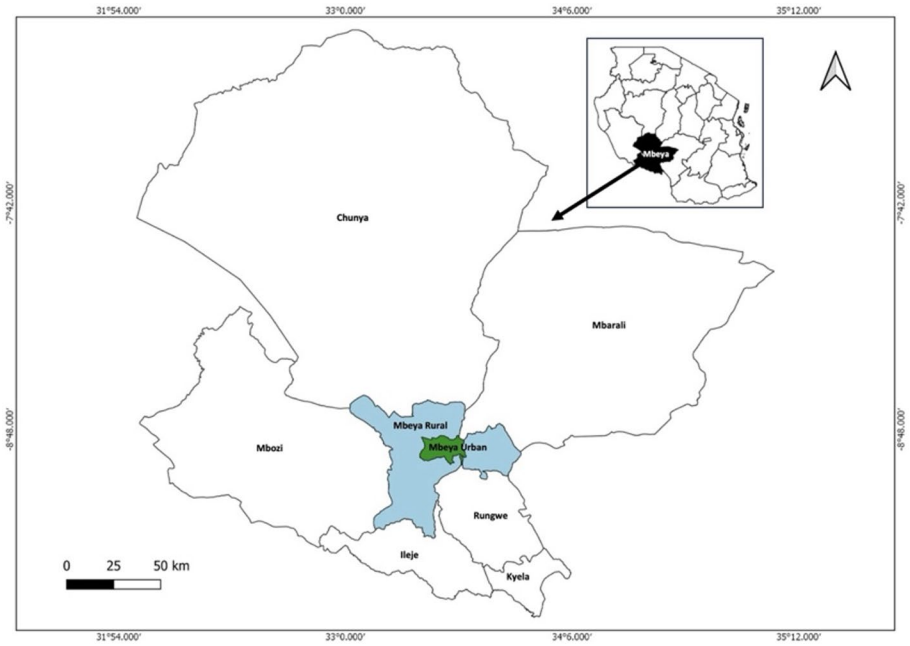

Fig. 1 Study site where the survey was conducted in Mbeya Urban (green) and Mbeya Rural (light blue) Districts

Irish potato farming is central to household livelihoods and contributes significantly to local and national economy.

2.2 Data collection

Data on Irish potato farming and the challenges, particularly insect pests and diseases in Mbeya urban and rural districts, were collected using household surveys (HHS) and focus group discussions (FGD) using methodologies outlined by [47]. The study was granted permits and ethical approval for collecting data from Mbeya Region (MMC/F32/7/VOL.IV/201) and throughout the study, the team adhered to national ethical standards for research involving farmers. In each selected village, a list of Irish potato farmers was obtained from village leaders and agricultural extension officers and used as a sampling frame. Respondents were randomly selected from this list, with one-third of the farmers in each village chosen for interviews, resulting in a total sample size of 225 (Table 1). The semi-structured questionnaire used comprised of four main sections (Table 2): (i) the socio-economic profile of farmers including information such as age, gender, education, household size, land ownership and sources of income; (ii) farm characteristics and practices including farm size, area dedicated to Irish potato cultivation, varieties cultivated, seed sources and yields; (iii) knowledge of Irish potato pests and diseases (iv) pest and disease management practices.

To minimize misidentification of pests and diseases, enumerators received training from agricultural experts at the Tanzania Agricultural Research Institute (TARI) to enhance their ability to accurately guide farmers during interviews. The survey also used local names and photographs of common Irish potato pests and diseases to ensure clarity. Farmers were asked to estimate yield losses as relative categories (major, average, or minor) rather than exact quantities, as these were easier to recall and compare. Prior to actual data collection, a pilot study was conducted to pretest the questionnaire, which was administered by trained enumerators recruited locally from Mbeya, with diverse

Table 1 Overview of sample size distribution by surveyed village in the study area

District	Ward	Village	Number of farmers	Sample size
Mbeya Rural	Igoma	Igoma	94	30
		Kimondo	81	27
		Mwanzanzi	78	26
	Utengule	Mbalizi II	48	16
Mbeya Urban	Iwambi	Ilembo	57	19
		Mayombo	36	12
	Iyunga	CCM	36	12
		Lumbila	51	17
		Lupeta	45	15
	Uyole	Igawilo	42	14
		Itezi Magharibi	54	18
		Nsalaga	57	19
Total (N)			679	225

Table 2 Overview of the information categories included in the questionnaire used

Data group	Description
Personal data	Gender; Age; Education; Household size; Land ownership
Farming characteristics and practices	Farm size; Sowing time; Type of seeds; Monocropping; Intercropping; Yields;
Knowledge of Irish potato pests and diseases	Most common pests and diseases in Irish potato farming
	Local names for pests and diseases
	Awareness and knowledge on pests and diseases
	Perceptions of impact to Irish potato yields
Pest management practices and pesticide use	Major crops cultivated
	Common methods of pests and diseases control
	Pesticide use; Pesticide products; Pesticide rates applied in the field
	Recommended label rates of pesticides
	Number of pesticide applications per season
	Common procedures of pesticide application and function status
	Criteria for the selection of pesticide products in use
	Decisions for pesticide spraying and application periods
	Perceptions of the effects of pesticide use
	Levels of knowledge about pesticide safety

knowledge about the study area. Before each interview, respondents were provided with a written consent form explaining the study objectives and seeking approval by signing the consent form before proceeding with the interview.

Conversely, FGDs were also conducted through organized community meetings [48], and were designed to complement and enrich the information collected through HHS. While the HHS provided data on variables such as farm size, sowing time, type of seeds, cropping systems, yields and pesticide use, the FGDs offered deeper qualitative insights that validated and contextualized these findings such as community-level consensus on common pests and diseases, their effects on yield and crop rotation or intercropping practices. The discussions also revealed nuanced pesticide-use practices such as product choice, application rates, spraying frequency and safety perceptions thereby clarifying household-level decision-making processes.

2.3 Data analysis

Data from the household survey and focus group discussions were cleaned, coded, and entered into Microsoft Excel before being exported to IBM SPSS (version 26) and for statistical analysis. Descriptive statistics, including frequencies, means and percentages, were used to summarize socio-economic characteristics of respondents and key variables related to Irish potato production and pest and disease management. To compare differences across wards, one-way ANOVA was applied for continuous variables such as farm size, yield, and pesticide application rates. Prior to running ANOVA, assumptions of normality were checked using the Shapiro–Wilk test, while homogeneity of variances was confirmed using Levene's test. For categorical variables, associations were examined using the Chi-square test of independence. Qualitative data from focus group discussions were transcribed, coded thematically and triangulated with quantitative findings to provide context and depth to the survey results. This mixed-methods approach ensured that both numerical trends and contextual explanations were captured, thereby strengthening the robustness of the conclusions. The level of significance was set at 0.05 and the means were separated using Turkey's HSD test.

3 Results

3.1 Socio-economic and farm characteristics of the respondents

Most of the farmers (61%) surveyed in the five wards were female (Table 3). The average age of respondents varied significantly across wards ($p = 0.0003$, $F = 5.56$), ranging from 39 years in Igoma to 46 years in both Iwambi and Utengule. The combined average age was 43 years (SD = 9), placing most farmers in the middle-age category. In terms of education, 70.6% of respondents had completed primary education, while 3.3% had no formal education. Those with tertiary education (college) comprised 8.2%, and secondary education accounted for 17.9%. Educational differences were statistically significant ($\chi^2 = 266.86$, $df = 3$, $p = 0.001$). The average household size across the five wards was 5 individuals (SD = 2), also significantly varied ($F = 2.56$, $p = 0.0398$). Most farmers owned land, with 68% reporting ownership, however, ownership levels varied, from 52% in Iyunga to 80% in Igoma ($F = 22.34$, $p = 0.0015$). On average, households owned 0.73 hectares of land (SD = 1), with Igoma having the highest average (1.4 ha) and Iwambi the lowest (0.8 ha). Irish potato was grown on an average of 1.3 ha per household (SD = 1.9), with wide variation ($F = 38.12$, $p = 0.0006$). Yields of Irish potato differed significantly between wards ($F = 96.37$, $p = 0.0001$), with the highest yield in Igoma (22.41 t/ha) and the lowest in Iwambi (1.13 t/ha). The mean yield across all wards was 6.9 t/ha (SD = 4.9). In terms of income, the highest average per-ha income was reported in Igoma ($1724) and the lowest in Iwambi ($87), with an overall average of $956/ha from Irish potato farming.

3.2 Irish potato cultivation practices

Sowing time varied significantly between wards ($\chi^2 = 10.11$, $df = 4$, $p = 0.057$) (Table 4). In Igoma, the majority of farmers (92%) planted between August and October, whereas in Iwambi, 78% sowed between January and February, and 22% between December and January. In Iyunga, sowing was mostly reported between November and December (87%) and December to January (13%). Utengule saw a majority (71%) sowing in January to February, with an additional 29% in December–January, while Uyole had a dominant sowing period of December to January (92%). This reflects both climatic and local

Table 3 Socio-economic characteristics of the respondents, Irish potato farming characteristics and yields ($N = 225$)

Sample size (N) = 225 Variable		Wards						Chi square and ANOVA
		Igoma	Iwambi	Iyunga	Utengule	Uyole	Mean (SD)	
Gender (%)	Male	40	48	39	44	29	39 (7.04)	$\chi^2 = 11.56$; df = 1; $p = 0.001$
	Female	60	52	61	56	71	61 (7.04)	
Education level (%)	None	8	0	0	0	8	3.3 (4.46)	$\chi^2 = 266.86$; df = 3; $p = 0.001$
	Primary	77	68	89	69	51	70.6 (13.82)	
	Secondary	12	16	9	25	27	17.9 (8.01)	
	College	2	16	2	6	14	8.2 (6.44)	
Age (years)	Mean (SD)	39 (7)	46 (5)	44 (13)	46(12)	42 (9)	43 (9)	df = 220; F = 5.56; $p = 0.0003$
Household size	Mean (SD)	6 (2)	6 (1)	5 (2)	5 (2)	5 (1)	5 (2)	df = 220; F = 2.56; $p = 0.0398$
Land ownership (%)	Mean (SD)	80 (42)	58 (11)	52 (3)	75 (35)	73 (32)	68 (25)	df = 219; F = 22.34; $p = 0.0015$
Land per household (ha)	Mean (SD)	1.4 (1.3)	0.3 (0.4)	0.4 (0.6)	0.6 (0.7)	1 (1.1)	0.7 (0.8)	df = 216; F = 10.85; $p = 0.0001$
IP farming (ha)	Mean (SD)	1.8 (1.3)	0.7 (0.7)	1.8 (3.8)	1.8 (2.1)	0.6 (1.3)	1.3 (1.9)	df = 216; F = 38.12; $p = 0.0006$
IP yields (t/ha)	Mean (SD)	22.4 (13.6)	1.1 (0.6)	1.4 (0.4)	1.9 (0.3)	7.5 (3.9)	6.9 (3.8)	df = 214; F = 96.37; $p = 0.0001$
Income ($/ha)	USD	1724	87	102	149	578	956	

* Statistical significance was considered at $p < 0.05$

Table 4 Sowing times, seed types and farming practices adopted by Irish potato farmers in Mbeya urban and rural districts ($N = 225$)

Sample size (N) = 225 Variable	Wards						Statistics
	Igoma	Iwambi	Iyunga	Utengule	Uyole	Mean	
(i) Sowing time							$\chi^2 = 10.11$; df = 4; $p = 0.057$
Jan–Feb	8	78	0	71	8	33	
Aug–Oct	92	0	0	0	0	18	
Nov–Dec	0	0	87	0	0	17	
Dec–Jan	0	22	13	29	92	31	
(ii) Seed type							$\chi^2 = 11.48$; df = 4; $p = 0.021$
Traditional/local seed	68	100	97	71	89	91	
Improved seed	32	0	3	29	11	45	
(iii) Farming practices							$\chi^2 = 19.6$; df = 4; $p = 0.001$
Intercropping	22	32	18	13	20	21	
Monocropping	78	65	82	87	78	78	
Crop rotation	0	3	0	0	2	1	

* Statistical significance was considered at $p < 0.05$

preference differences in planting schedules. With regard to seed types, traditional or local varieties dominated across all wards, used by an average of 91% of farmers ($\chi^2 = 11.48$, df = 4, $p = 0.021$) (Table 4). This was particularly evident in Iwambi (100%) and Iyunga (97%), while Igoma and Utengule showed slightly higher uptake of improved seed types (32% and 29%, respectively). The limited use of improved seeds i.e. only 3% in

Iyunga and 11% in Uyole suggests a gap in access or awareness regarding certified seed varieties, despite potential benefits for yield and pest resistance.

In terms of farming practices, monocropping was predominant in all wards, reported by 78% of farmers on average (χ^2 = 19.6, df = 12, p = 0.075) (Table 4). The highest rates were seen in Utengule (87%) and Iyunga (82%). Intercropping was more common in Iwambi (32%) and Igoma (22%), with less frequent adoption in other wards. Crop rotation, a known cultural control strategy, was rarely practiced, cited by only a few farmers in Iwambi (3%) and Uyole (2%), and not at all in other wards. This low uptake of rotation and intercropping indicates limited integration of sustainable pest and disease management strategies, potentially due to lack of extension services or entrenched traditional practices. Although majority of farmers use farm-saved seeds, notably 90% of them reported checking and sorting the seed prior to planting to eliminate pest-damaged seeds. This demonstrates strong awareness of proper seed handling, which is a critical step in improving overall productivity.

3.3 Farmers' perceptions and knowledge of pests and diseases of Irish potato

Most farmers from the five wards perceived insect pests as the most important constraint in Irish potato production. The most frequently mentioned pests included aphids, reported by 83% of respondents on average (ranging from 78% in Utengule to 89% in Igoma), followed by whiteflies (71% overall), with notable ward-level variation (χ^2 = 14.43, df = 4, p = 0.044) (Fig. 2a). Potato tuber moth, was mentioned as another key pest, particularly in Igoma (58%), and was reported by 39% of farmers overall. Its occurrence varied significantly across wards (χ^2 = 12.75, df = 4, p = 0.026), indicating differing pest pressure or detection levels.

Diseases were equally important in constraining Irish potato production. Early blight was the most widely reported disease, cited by 91% of farmers overall, and by all farmers (100%) interviewed in Iwambi, Iyunga (97%), and lower reporting in Utengule (71%) (Fig. 2b). This difference was statistically significant (χ^2 = 11.48, df = 4, p = 0.021). Late blight followed, affecting 45% of farmers on average but with sharp contrasts across wards, 72% in Iyunga, 71% in Igoma, but only 14% in Utengule and 21% in Iwambi (χ^2 = 27.40, df = 4, p = 0.001). Fusarium wilt was reported by 29% of farmers, again with significant ward-level variation (χ^2 = 15.90, df = 4, p = 0.0003), highest in Iwambi (58%) and lowest in Uyole (11%).

In terms of impact, farmers reported varying degrees of yield loss due to pests. Although 21% of respondents on average reported major losses (highest in Iwambi at 32%), the majority (53%) categorized losses as minor (Table 5). There was no statistically significant variation in pest-related loss across wards (χ^2 = 19.60, df = 12, p = 0.075), suggesting generally consistent perceptions of pest damage. Conversely, losses attributed to diseases showed more variation across the five wards. While 43% of farmers reported average losses, 49% indicated minor losses, and only 7% reported major losses on average, with the highest major loss noted in Iyunga (14%) (Table 5). The ward differences in disease-related losses were statistically significant (χ^2 = 29.90, df = 12, p = 0.003), highlighting variability in disease severity, crop susceptibility or management effectiveness. Although other constraints such as water shortage, soil fertility, weed infestation and market access were mentioned, they were perceived as less critical compared to pest and disease issues.

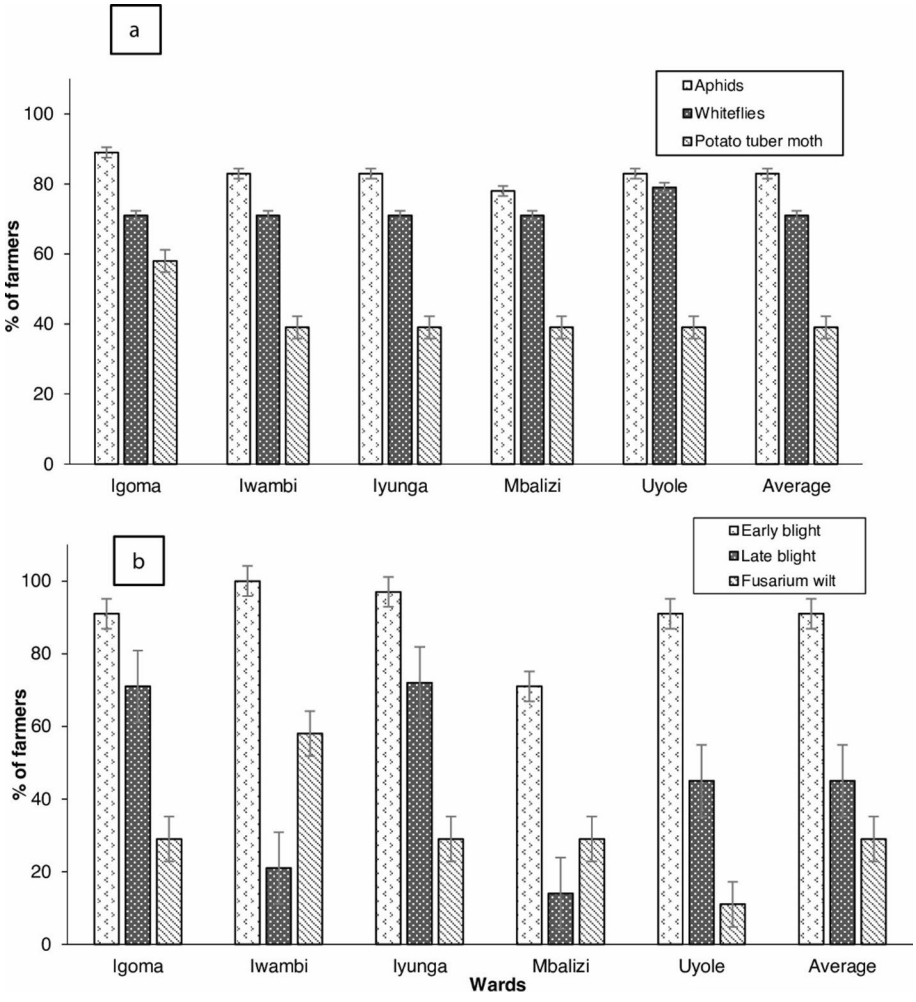

Fig. 2 Major pests (**a**) and diseases (**b**) in Irish potato farming as reported by farmers in Mbeya urban and rural districts

3.4 Pests and diseases management strategies

Majority of farmers (92%) reported using chemical pesticides such as Profenofos as their primary strategy to control insect pests in Irish potato production (Table 5). Usage was reported by all farmers interviewed in Igoma (100%), and remained high across the other wards: Uyole (96%), Iyunga (89%), Utengule (88%), and Iwambi (87%). This variation was statistically significant (χ^2 = 12.15, df = 4, p = 0.016), suggesting differences in access to agro-dealers, crop intensities or exposure to extension services. Use of cultural practices such as crop rotation or intercropping for pest control was relatively low, averaging 8% across wards, but varied significantly (χ^2 = 27.24, df = 4, p < 0.0001). The highest adoption was observed in Utengule (12%) and Iwambi (9%), while only 3% of farmers in Uyole, 6% in Iyunga, and none in Igoma reported cultural control for pests (Table 5). The use of botanical extracts for pest management was extremely limited, though still statistically significant across wards (χ^2 = 57.78, df = 4, p < 0.0001). Only 4% of farmers in Iwambi, 5% in Iyunga, and 1% in Uyole used botanicals. No farmers in Igoma or Utengule reported using such alternatives. No farmer in any ward indicated that they did "nothing" to control insect pests, reflecting a high level of engagement in crop protection.

Table 5 Loss and management strategies reported by Irish potato farmers in Mbeya urban and rural districts ($N = 225$)

Sample size (N) = 225	Wards						Statistics
Variable	Igoma	Iwambi	Iyunga	Utengule	Uyole	Mean	
(i) Loss due to insect pests							$\chi^2 = 19.6$; df = 12; $p = 0.075$
Major	22	32	18	13	20	21	
Average	25	10	39	25	20	24	
Minor	53	55	43	56	60	53	
I don't know	0	3	0	6	0	2	
(ii) Loss due to diseases							$\chi^2 = 29.9$; df = 12; $p = 0.003$
Major	7	6	14	6	2	7	
Average	52	26	66	19	51	43	
Minor	41	65	20	75	45	49	
I don't know	0	3	0	0	2	1	
(iii) Insect pest control methods							
Chemical sprays (pesticides)	100	87	89	88	96	92	$\chi^2 = 12.15$; df = 4; $p = 0.016$
Cultural	0	9	6	12	3	8	$\chi^2 = 27.24$; df = 4; $p < 0.0001$
Botanical extracts	0	4	5	0	1	2	$\chi^2 = 57.78$; df = 4; $p < 0.0001$
Do nothing	0	0	0	0	0	0	
(iv) Disease control methods							
Chemical sprays (fungicides)	98	84	93	94	90	72	$\chi^2 = 174.29$; df = 4; $p < 0.0001$
Cultural	2	16	3	6	4	28	$\chi^2 = 21.25$; df = 4; $p < 0.001$
Botanical extracts	0	0	4	0	6	2	$\chi^2 = 9.28$; df = 4; $p = 0.055$

*Statistical significance was considered at $p < 0.05$

For disease control, Mancozeb and Cymoxanil based fungicide were widely reported, with an overall average of 72%, and highest adoption reported in Utengule (94%), Iyunga (93%), and Uyole (90%) (Table 5). Igoma also reported high usage (98%), while Iwambi had slightly lower adoption at 84%. These differences were highly significant ($\chi^2 = 174.29$, df = 4, $p < 0.0001$), possibly reflecting varying disease pressures or access to fungicides. Cultural methods for disease management showed wider variation and an average adoption of 28% across wards ($\chi^2 = 21.25$, df = 4, $p < 0.001$). The highest uptake was again in Iwambi (16%), followed by Utengule (6%), Uyole (4%), Iyunga (3%), and Igoma (2%). Use of botanical extracts for disease control was minimal, with the highest usage recorded in Uyole (6%) and Iyunga (4%), and none reported in the other wards. While the difference approached statistical significance ($\chi^2 = 9.28$, df = 4, $p = 0.055$), the low overall adoption suggests limited awareness or access to these alternatives.

4 Discussion

4.1 Socio-economic profile of respondents

The socio-economic profile of respondents revealed that Irish potato farming in Mbeya is dominated by male-headed households, with the majority of farmers fall under middle-age category. This age distribution reflects a relatively mature farming population actively engaged in agriculture, which is consistent with previous studies in the Southern Highlands of Tanzania and other potato-growing regions of East Africa [15, 49].

However, this also suggests limited youth involvement in potato production, an issue that has been widely acknowledged as a barrier to agricultural innovation and long-term sustainability [50, 51]. Education levels were generally low, with most farmers having only primary education or none. This has implications for information uptake, especially with respect to the adoption of improved agronomic and pest management technologies. Low literacy has been consistently linked with poor adoption of Integrated Pest Management (IPM) strategies and limited interpretation of pesticide labels, as observed in studies from Uganda and Kenya [52, 53]. In contrast, studies by [42, 54] showed that targeted training and farmer field schools can significantly offset the disadvantages posed by low formal education, enhancing decision-making capacity regardless of literacy levels.

The majority of farmers had been doing Irish potato cultivation for more than a decade, which indicates a strong familiarity with the crop. However, as the results showed, experience alone did not necessarily correlate with improved yields or adoption of best practices. Similar findings were reported by [55] in Kenya, where long-term experience in potato farming did not always translate into higher productivity due to climate change, limited access to improved seed and advisory services. Regarding landholding, average farm sizes were relatively small with notable differences between wards. Igoma reported the largest landholdings, possibly due to peri-urban or rural location advantages, while Iwambi had the smallest, likely reflecting urban encroachment and land scarcity. These findings align with the broader trend of land fragmentation in urban-adjacent farming communities in Tanzania and other developing countries [56, 57]. Contrastingly, studies in Ethiopia and Eritrea have shown larger average land sizes among Irish potato farmers, which are often associated with higher input use and better market orientation [58, 59]. The socio-economic profiles of farmers across the five wards reveal both opportunities and constraints in adoption of sustainable farming practices, emphasizing the need for interventions that will improve awareness among farmers to enhance Irish potato productivity.

4.2 Cultivation practices and seed use

Irish potato cultivation was low per household across the five surveyed wards, with significant inter-ward variability. Igoma and Uyole recorded slightly larger average areas under cultivation compared to Iwambi which lies closer to the city center and experiences greater land pressure. These differences align with previous studies suggesting that urban expansion, land tenure insecurity and fragmentation often constrain cultivation area in peri-urban settings [60, 61]. The predominance of monocropping among farmers in the study area reflects a trend seen across much of sub-Saharan Africa, where farmers prioritize single-crop systems for market-oriented production, especially when land is limited or under customary tenure [62, 63]. However, this reliance on monoculture contradicts recommendations for diverse cropping systems to enhance resilience against pests and climate shocks [64, 65]. In contrast, in countries such as Sweden, Rwanda and Ethiopia, higher rates of intercropping and crop rotation have been observed, often attributed to more active government-led extension programs and stronger farmer cooperatives promoting good agronomic practices [66–68]. The fact that only 8% of farmers in the current study adopted crop rotation and just 21% intercropped indicates a knowledge or capacity gap in sustainable intensification approaches.

Regarding seed systems, the vast majority of farmers across all wards relied on traditional or local seed varieties. This heavy dependence is not unique to Mbeya, similar trends have been observed in Kenya and other East African countries, where informal seed systems continue to dominate due to affordability, familiarity and unavailability of certified seed [10, 69]. However, the reliance on local seed limits productivity gains, as traditional varieties are often susceptible to common pests and diseases such as late blight, bacterial wilt and nematodes [11, 70]. In Ethiopia, for instance, the use of certified seed has been positively correlated with both yield increase and disease tolerance, yet seed adoption remains uneven even there due to supply chain challenges and inadequate awareness [71]. Notably, farmers in the study area showed strong seed handling practices, by checking and sorting seed before planting, thus the low use of improved or certified varieties suggests systemic limitations such as high seed costs, limited local multiplication and distribution, and weak linkages between formal seed producers and smallholder farmers rather than lack of knowledge [52, 72, 73]. Furthermore, no respondent reported seeking extension advice on seed selection or agronomic planning, highlighting the persistent disconnect between smallholders and advisory services in rural Tanzania. This finding contrasts with report from the International Potato Centre, where sustained community-based seed dissemination efforts have significantly improved access and uptake of high-yielding varieties [74]. The farming practices and seed use reflect a mixture of traditional norms, land constraints and institutional gaps that shape farmer behavior. While some awareness of good practices exists, such as seed sorting, limited adoption of sustainable practices and improved inputs highlights the need to strengthen farmer education, input access and research-extension-farmer linkages.

4.3 Perception of constraints and pest identification

The results indicate that farmers in the five wards of Mbeya perceive insect pests and diseases as the most significant constraints to Irish potato production, similar to other Irish potato-growing regions in East Africa and beyond [11]. The prominence of aphids and whiteflies in the study area reflects broader regional patterns in Irish potato production. Similar findings have been reported in Kenya and the Democratic Republic of Congo, where these sap-sucking insects are recognized as major constraints, largely because they thrive under conditions of continuous cropping and favorable weather [27, 75]. In contrast, the potato tuber moth was reported by fewer farmers overall but was cited more in Igoma likely due to underreporting or misidentification of the pest due to its cryptic nature [76].

On the disease side, early blight (*A. solani*) was perceived as the most important disease cited by majority of farmers in the study area. This mirrors findings from India and other parts of the world where early blight is increasingly recognized as a major constraint, especially under warming and fluctuating rainfall conditions [77–79]. Interestingly, late blight (*P. infestans*), which is globally considered the most devastating potato disease, was reported by few farmers in the study area. This discrepancy may stem from microclimatic variation or farmers' difficulty in distinguishing late blight from early blight [80, 81]. Fusarium wilt, soft rot and blackleg were reported less frequently, consistent with their lower incidence in East African potato systems but still posing localized threats.

Farmers' perceptions of the severity of pest and disease impacts varied across the five wards visited. Most categorized the losses as minor or moderate, with few reporting severe damage. Similar perceptions have been documented in Uganda and Malawi, where farmers acknowledge considerable losses but often underreport their magnitude due to lack of systematic monitoring [12, 82]. While other constraints such as water shortage, declining soil fertility, weed infestation and market limitations were acknowledged, they were considered less critical than pest and disease problems. This prioritization reflects findings from Kenya and South Africa, where biotic constraints are often ranked above abiotic and socio-economic factors [10, 83, 84]. In general, farmer's knowledge gaps in identifying certain pests and diseases suggest the need for targeted farmer training and improved diagnostic support to enhance management practices and reduce yield losses.

4.4 Pest and disease management strategies

The pest and disease management strategies employed by Irish potato farmers in Mbeya reveal a strong reliance on synthetic agrochemicals which reflects broader regional trends. For instance [85], documented similar chemical-centric approaches globally, where the majority of potato farmers relied on conventional pesticides for controlling foliar pests and diseases. Similarly [86], found pesticide use among potato growers in Nepal to be widespread, with minimal training on safe handling or alternatives. While such practices are effective in the short term, the over-reliance on synthetic inputs raises environmental and health concerns, including pesticide resistance, residue accumulation and negative effects on non-target organisms [44, 87]. The significant variation in pesticide and fungicide use across wards in this study suggests unequal access to inputs, extension services or knowledge. Igoma, for example, had a 100% pesticide usage rate but no reported fungicide use, despite widespread disease presence. This is concerning given that early blight and late blight were among the most cited constraints. The complete absence of fungicide use in this ward contrasts with Utengule and Iyunga, the majority of farmers used fungicides. These inconsistencies could be attributed to local input market dynamics or differing levels of disease recognition, as also observed in a study by [43], which linked low fungicide use to farmers' inability to distinguish between pest and disease symptoms.

Cultural control strategies such as crop rotation and intercropping with maize or beans were moderately adopted for disease and pest management. The statistical significance of their variation across wards further emphasizes the influence of local practices, land availability, and possibly exposure to training or demonstration plots. In Kenya [88], found a similar pattern where a small fraction of potato farmers practiced rotation or other cultural controls, citing knowledge gaps and land fragmentation as barriers. Conversely, studies by [89, 90] observed higher cultural method adoption in areas where participatory IPM training had been conducted. This contrast suggests that with targeted extension services, cultural practices can be scaled effectively. Botanical pesticide use in this study was very low and varied significantly across wards, a trend mirrored in previous research. Studies by [91, 92] reported that fewer farmers are using plant-based formulations due to inconsistent efficacy and poor access to preparation knowledge. However, in some parts of Africa, local NGOs have supported the use of neem-based, chili-garlic and other bio-extracts with notable success and farmer acceptance [11, 79].

The relatively higher use of botanicals in wards like Iyunga and Uyole could indicate either spillover from such interventions or informal knowledge networks promoting eco-friendly methods.

None of the farmers in any ward reported doing "nothing" to manage pests or diseases. This reflects a proactive stance among smallholder farmers and a baseline awareness of the importance of crop protection. However, the overall dominance of chemical methods coupled with limited uptake of integrated approaches highlights an ongoing gap in the adoption of Integrated Pest Management (IPM). Several studies including [93, 94] have emphasized the effectiveness of IPM in increasing yields and reducing pesticide use when supported by institutional training and farmer field schools.

5 Conclusion

This study examined the knowledge, perceptions and practices of smallholder farmers in managing pests and diseases of Irish potato in Mbeya, Tanzania. Farmers demonstrated considerable awareness of the key constraints, especially diseases such as early blight and late blight, and pests such as aphids and whiteflies, and actively engaged in crop protection using predominantly chemical pesticides. However, reliance on traditional seed, low uptake of cultural practices and inconsistent disease recognition indicate significant gaps in knowledge and resources. Ward-level differences in yields, input use and management practices highlight the influence of local conditions and access to extension services. Promoting IPDM through targeted training, improved input delivery systems, and strengthened extension services is crucial to enhance productivity and sustainability. Future research should focus on evaluating the effectiveness of locally adapted IPDM approaches, improving farmer access to certified seeds and bio-based controls and supporting farmer-extension linkages to improve yields and build resilience in Irish potato farming.

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Author contributions
**HL: ** Conceptualization, Data curation, Formal analysis, Fund acquisition, Project administration, Methodology, Writing-original draft, Writing-review and editing.

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Data availability
Data will be made available on reasonable request to the corresponding author.

Declarations

Ethics approval and consent to participate
The study was granted permits and ethical approval for collecting data from Mbeya Region (MMC/F32/7/VOL.IV/201) and throughout the study, the team adhered to national ethical standards for research involving farmers.

Consent for publication
Before each interview, respondents were provided with a written consent form explaining the study objectives, and informed consent was obtained for both the interview and the publication of research findings, with their identities kept anonymous.

Competing interests
The authors declare no competing interests.

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