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Impacts and Management Strategies of Common Potato (*Solanum tuberosum* L.) Pests and Diseases in East Africa

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Abstract Potatoes are attacked by numerous pests and diseases in the farmer fields with high potential to cause low to high yield losses. The direct and indirect nature of impact and the ability to attack at the fields and stores make potato tuber moth the most important pest in the production of potatoes. Moreover, the capacity of pathogens to have a wide range of host plants and ability to live in the soil make diseases such as Bacterial wilt, Late blight, and Verticillium wilt difficult to offer effective and lasting management solutions. For farmers to sustainably manage these constraints, the control must begin right from the initial stage of selection of fields and planting materials- all these must be free of pests and diseases. During production, farmers should manage these pests and diseases through improved soil and nutrient management and chemical application. Use of chemicals should be done with much care to avoid pollution and effect on beneficial organisms that would otherwise cause ecological imbalance.

Keywords Disease management, Late blight, *Meloidogyne spp*, Potato tuber moth, Potato virus, Pest management, *Solanum tuberosum*, Verticillium Wilt

1. Introduction

Potato (*Solanum tuberosum* L.) is one of the most important crops in East Africa with a potential to abate hunger due to higher yield per unit area of land compared to maize (UARC, 1990). According to the International Potato Center (CIP) (2008), one hectare of Potato can yield 2-4 times the food value of grain crops and produces more food per unit of water than any other major crop and being up to seven times more efficient in using water than cereals. However, the yields have remained low at 5-9 t/ha compared to the achievable farmer yield of about 20 t/ha in the region (Gildemacher *et al.*, 2009; Al-Dalain, 2009; Namwata *et al.*, 2010). Such a high yield gap is could be linked to pest and disease attacks, among other constraints. Potato yield losses due to pest and disease attacks could be as high as 100% depending on crop tolerance level, climatic conditions, soil, type of pest and disease (Olanya *et al.*, 2002). The prevalence is high due to the warm and wet climatic conditions experienced in the region. A survey carried out on potatoes sold at rural markets in Kenya showed that 99.6% of all sampled tubers had viral diseases (Gildemacher *et al.* 2007). Such high levels of incidences are due to the constant use of farmer-saved seeds which have caused build-up and transfer of pathogens from generation to the other. Gildemacher *et al.* (2009) reported that only 41%, 26% and 44% of farmers in Kenya, Uganda, and Ethiopia renew their seeds, a practice which is done after 6, 7 and 3 seasons respectively. Early blight, Common scab, Verticillium wilt, Late blight, Bacterial wilt diseases have been confirmed to affect potato farmers in East Africa (Low, 1997; Tumwine *et al.*, 2002; Nyankanga *et al.* 2004; Wakahiu *et al.* 2007; Gildemacher *et al.*, 2009; Muthomi *et al.*, 2012). On the other hand, pest attacks have been confirmed and reported across all potato producing zones. Most important pests reported in the region include Thrips, potato tuber moth (*Phthorimaea operculella*), cutworm and nematodes (Das & Raman, 1994; Kfir, 2003; Capinera, 2008; Nyasani *et al.*, 2012; Onkedi *et al.*, 2014; Ghebreslassie, 2017). Potato tuber moth is one of the most devastating pests causing up to 100% yield loss due to its capacity to attack at the field and continue affecting tubers at the store (Ojero & Mueke, 1985; Okonya & Kroschel, 2016). The review, therefore, aimed to present economic impacts and management strategies of these common potato pests and diseases for adoption by farmers in East Africa Region.

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2. Management of Common Potato Pests and Diseases

Potatoes are affected by several insect pests and diseases causing both direct and indirect yield losses. The general pest and disease management strategy involves proper implementation of integrated pest management (IPM) - a broad-based approach that integrates practices for economic control of pests in the most promising and environmentally safe option. The use of synthetic pesticides under IPM should be done under great care and only in situations where other strategies have proved ineffective or under emergency (Otieno, 2019). Some of the most effective pest and disease management strategies wide wider application include;

- **Proper monitoring and scouting**: The frequency of scouting depends on the pest, crop, weather, and stage of growth. Better scouting process ensures early detection and execution of control strategy. During field scouting, farmers should move in a traverse using the "W" pattern while identifying and recording any symptom and sign of crop attack.
- **Adoption of better cultural practices**: Practices such as proper field selection to avoid areas with already existing potato pests and diseases is a very crucial initial step towards constraint management. This means that proper keeping of farm history records (on diseases and pests) is required for better field selection. The field selection practice is, however, facing threat from the ever-shrinking farm sizes due to subdivision leading to limited space for selection. Proper fields preparation early in the dry season helps kill pathogens before planting crops.
- **Use of certified and disease and pest free seeds**: During production, farmers need to select tubers from healthy mothers, in the case of farmer-saved seeds, or purchase seeds from certified dealers to avoid the spread of pests and diseases. Again, farmers need to reduce the level of seed tuber recycling, a practice that has always been linked with increased pest and disease build-up. Farmers should ensure that only varieties tolerant to these pests and disease and have better yield levels are selected for production.
- **Practice legume-brassica-potato-cereal rotation system**: Crop rotation has been widely accepted as a means of keeping potato pathogens below economic thresholds. The common mechanisms of control are through breaking the lifecycle and repelling of pests. In addition to pathogen control, the program also improves soil structure and fertility through biological nitrogen fixation and soil organic matter build-up when legumes are incorporated.
- **Use of well-decomposed manure**: Use of partially decomposed manure/compost derived from plant materials especially crops residues previously infected by diseases could provide a route for reinfection as pathogens are potentially transferred back into the field. Therefore, proper composting of organic materials including potato residues to kill pathogens and pests before applying back into the farm as manure should be ensured.

2.1. Impacts and Management of Important Potato Pests

Potatoes are affected by a number of insect pests causing both direct and indirect yield losses. Weekly scouting for caterpillars during the first 30 days after planting; throughout the vegetative phase scouting for whiteflies, aphids, and thrips; and during tuber bulking scouting for millipedes and tuber moths is important for prompt initiation of a better control strategy.

2.1.1. Nematode (*Meloidogyne spp*)

Several nematode species affect potato yields (Medina *et al.*, 2017). The pest damage roots through feeding thereby reducing water, nutrient uptake and accumulation. The attacked tubers have lesions, rot and shrivel leading to far and wide economic losses (Hay *et al.*, 2016; Coyne *et al.*, 2018).

Several control strategies have been recommended: Tuber seed treatment with hot water before planting has been found effective (Youssef, 2013). Use of antagonistic plant species such as *Crotalaria spectabilis, C. juncea, Tagetes patula, T. minuta, T. erecta, and Estizolobium spp* could be adapted as intercrop or edge plants in the farm (Embrapa, 2015). Rotating potato with barley is effective in controlling *Globodera rostochiensis* and has reported up to 87% reduction in attack (Senasica, 2013). Retention of crop residues under no-till has also been found to reduce the effect of nematode (Otieno, 2017). Application of biopesticides, use of products developed from microorganisms such as, *Pochonia chlamydosporia*, *Bacillus firmus*, *Paecillomyces lilacinus*, and *Trichoderma* spp., with the capacity to attach and parasitize on the nematode or eggs leading to their death have been recommended (Atkins *et al.*, 2003; Yang *et al.*, 2012; Castillo *et al.*, 2013; KARI, 2014). Under heavy build-up, application of nematicide chemicals may be necessary- chemicals such as methyl bromide, Aldicarb, fenamiphos, oxamyl, 1, 3 dichloropropene (1, 3 ‑ D), dazomet and metam ‑ sodium have been found to offer some level of control (Onkendi *et al.*, 2014). These nematicides could be applied about 2 weeks to planting or at planting in the planting holes (KARI, 2014).

2.1.2. Cutworm (*Agrotis spp*)

The impact of cutworms is high during droughts and in new and succulent sprouts. Due to their sporadic nature, the impact is not easily quantified. However, under heavy infestation, yield loss of about 20-37% has been reported by Atwal, (1976).

To manage the pest, farmers may use family labour to physically collect and kill cutworms from the fields. This should be done in the morning or evening when the temperature is low and pest is actively feeding. This practice could be aided using rice brans placed strategically in the field to attract the worms which are then collected and killed. The crops could also be sprayed continuously with neem leaves or neem seed extract for eco-friendly control (Campos *et al.*, 2016). Use of synthetic chemical compounds such as

Chlorpyriphos 20 EC at 2.0 kg/ha, quinalphos 25 EC at 2.0 kg/ha has been found effective towards cutworm control (Tripathi *et al.*, 2003). Poison Bait (Dipterex +Sugar + Rice husk) has also proved effective- these baits are placed strategically on permanent potato plots where they attract and kill the worms that feed on them (Shakur *et al.*, 2007).

2.1.3. Potato Aphids

The most important Aphids species include *Myzus persicae*, *Macrosiphum euphorbiae*, and *Aulacorthum solani* (Harrington *et al.*, 1986). Aphids directly cause yield losses through leaf curl caused by feeding and black sooty mould that grows on the sugary excrement thereby lowering photosynthetic capacity of plants. Indirectly, the pest transmits viral diseases which cause serious losses in potato fields (Robert *et al.*, 2000; Radcliffe & Ragsdale, 2002).

The build-up of this pest could be controlled naturally through common enemies such as ladybird beetles, both adult and grub and syrphid larvae in potato fields (Tschumi *et al.*, 2016). Farmers may encourage survival and multiplication of these natural enemies through reduction in the use of broad-spectrum pesticides and increased cultivation of nectar-producing edge plants to attract these enemies. Under heavy infestation, pesticides could be sprayed to reduce the population. Application of bio-pesticide products (e.g. *Lecanicillium*; *Lecanicillium longisporum* (Vertalec®), and *Lecanicillium attenuatum* (CS625) (Kim *et al.*, 2007); plant extract (e.g. Azatrol (1.2% azadirachtin), Triple Action Neem Oil (70% neem oil) and Pure Neem Oil (100% neem oil) (Shannag *et al.*, 2014); and synthetic chemical formulations (e.g. phorate 10G, carbofuran 3G, acephate 75SP, lindane 6.5 WP) (Konar & Paul, 2005) have been reported to be effective.

2.1.4. Thrips

The *Frankliniella schultzei* is the commonly found potato thrip species in the region (Nyasani *et al.*, 2012). Thrips suck potato plant sap from soft tissues causing leaves to curl and dry under heavy attack. This pest has also been associated with the transmission of viral diseases in potato fields (Marchoux *et al.*, 1991; Jones, 2005).

The effect of thrips is highly influenced by crop health. Therefore, keeping crops healthy is of great importance towards reducing the level of damage- adequate water and nutrient supply to crops are highly recommended in maintaining crop healthy. Use of reflective mulches (such as silver polyethylene and pieces of cardboard with aluminum foil) to illuminate underneath of leaves has been found to help in repelling these insects (Riley & Pappu, 2000; Reitz & Funderburk, 2012; Lal Bhardwaj, 2013). The use of chemical method is somehow difficult and less effective since thrips hide in leaf sheaths and underneath and flower bracts which are hard to reach with chemical sprays. However, if done well, application of *Azadirachta indica* formulation (azadirachtin at 0.03% EC), and imidacloprid at 0.02% could be effective (Anuj, 2009).

2.1.5. Potato Tuber Moth (*Phthorimaea operculella*)

Potato tuber moth is the most important pest affecting production of potatoes in warm and dry conditions experienced in East Africa. The attack begins from the field and proceeds into the store with the caterpillars creating tunnels leading to 100% tuber yield loss if no intervention is made (Alvarez *et al.* 2005; Ahmed *et al.*, 2013). The excrement in the tunnels also attracts fungal and bacterial growth leading to further infections and damages. The holes created provide secondary infection- entry points for pathogens.

The pest could be controlled naturally through conservation of natural enemies (e.g. wasps and Larvae of lacewings, big-eyed bugs, ground beetles, earwigs, and rove beetles) which prey on all stages of tuber moth (Symington, 2003, Alvarez *et al.* 2005). Cultural practices such as deep planting (10-15 cm) coupled with 2-3 hilling during growing periods and proper irrigation to avoid cracks during dry periods have been found to reduce pest attack (Hanafi, 1999; Clough *et al.*, 2010). Neem plant has repellent property hence when leaves are used together with mulch could help keep the tuber moths ways. Farmers could also practice improved cropping systems- intercropping potatoes with pepper, onion or peas and rotation with non-solanaceous crops have been found to help in breaking the life cycle of potato tuber moth resulting to low population and build-up on the farm (Lal, 1991). Use of plant-extracts like oil from neem and sunflower seeds could reduce storage losses to 25% (Salem, 1991). However, care must be taken to avoid over-application of these oils that may reduce tuber respiration resulting in low quality as they turn black and become flaccid. Control of potato tuber moth using synthetic chemical products is ineffective once the pest is inside the tubers. However, farmers could spray the plants with neem leaf extracts, *Bacillus thuringiensis*, fenvalerate, methamidophos, acetamiprid, imidacloprid, and methomyl products which have been found to be effective (Kroschel & Koch, 1996; Rondon, 2010; Vaneva-Gancheva & Dimitrov, 2013).

2.2. Impact and Management of Important Potato Diseases

Diseases are the most important component of biological constraint to potato production as they affect both above and below ground parts. Once in the tubers, the disease continues to develop and multiply even when the products are in stores- meaning 100% yield loss is possible depending on the period and conditions of storage, type of disease and multiplication rate. Therefore, scouting of fungal, viral and bacterial diseases should begin immediately after sprout emergence and continue until harvesting.

2.2.1. Early Blight (*Alternaria solani*)

The pathogen thrives in warm and wet conditions and attacks both above and below ground potato parts. It lowers the quality of the products through the formation of brown to black, dry corky rot in the tubers. Yield losses of up to 80% have been reported (Stevenson *et al.* 2001; Olanya *et al.*, 2009; Horsfield *et al.*, 2010; Tsedaley, 2014).

Control of Early blight is difficult due to its capacity to produce huge amounts of secondary inoculum and survival in the soil (Campo *et al.*, 2007; Pasche *et al.*, 2004). Being a soilborne disease, the pathogen could easily be dispersed by irrigation water. Therefore, farmers should regulate water and avoid splashing soils onto plant leaves during irrigation (Olanya *et al.*, 2009). At harvesting, farmers should avoid causing injuries to the tubers that could lead to further contamination and spread in the store. The storage structures should provide cool and aerated conditions that promote rapid suberization of bruises and cut edges to keep away the pathogens as they are unable to infect through intact periderm (Tsedaley, 2014). Chemical application is also a feasible strategy- use of Ridomil Gold, Antracol, and difenoconazole from 30 days after planting has been found effective (Horsfield *et al.*, 2010).

2.2.2. Late Blight (*Phytophthora infestans*)

The disease attacks crops, mostly during cool, cloudy and wet conditions and may results in 100% yield loss under heavy attack on susceptible varieties. Under good management but without fungicide sprays, yield losses could be 40-50% for the moderately resistant varieties and 50-70% for the more susceptible varieties (Ojiambo *et al.*, 2001; Rahman *et al.*, 2008). Attacks on the fields reduce the photosynthetic capacity of the plants. Due to both field and postharvest losses and control requirement, Late blight is classified as the most expensive disease of potato crop (Cooke *et al.*, 2011).

Proper irrigation management through minimized wetting on potato leaves and ensuring air circulation to dry leaves is important in disease management. Chemical control should be used cautiously and only under heavy attack- Products such as Ridomil Gold, Dithane M-45, Filthane M-45, Secure, Melody Duo have been found effective and recommended for use (Nyankanga *et al.*, 2004; Rasheed & Khan, 2008; Rahman *et al.*, 2008).

2.2.3. Common Scab (*Streptomyces scabies*)

Common scab incidence has been shown to be related to soil pH, though the extent and optimum level is a point for further debate. Most researchers have leaned towards alkaline conditions (pH 7-8) to reduce disease incidences and yield losses but this needs to be done cautiously without affecting the next crop in the subsequent season (Waterer, 2002). Use of manure has also been floated as a strategy for the management of scab disease (Conn & Lazarovits, 1999). This could be, in parts, due to the ability of manure to raise soil pH and attract natural enemies (Otieno *et al.*, 2018). But the optimum rate of manure application is not clear and is likely to be affected by the quality and availability. Use of *Pseudomonas* species and vermicompost are some of the technologies which have shown good efficacy and being considered for the management of the disease (Singhai *et al.*, 2011).

2.2.4. Verticillium Wilt (*Verticillium albo-atrum/ Verticillium dahlia*)

Verticillium wilt disease is caused by a soil-borne pathogen with broad host range – annual to perennial plants- and could cause up to 50% yield loss in the affected fields (Johnson & Dung, 2010). The attacked potato plants wilt and dry up with time. Tubers have discoloration, hence low market value, though they are edible.

Controlling Verticillium wilt disease is very challenging due to the wide range of host plants that exist at any given time in the farmer fields. However, rotating potatoes with cereals and non-host plants have shown a significant reduction of the disease depending on the period of rotation. According to Larkin *et al.* (2011), significant reduction requires 4-6 years of rotation and the use of green manure. Under irrigation system, farmers are required to maintain soil moisture at 70-75% during the vegetative stage and 80% during tuberization to reduce the amount of infection (Powelson & Rowe, 2008; Johnson & Dung, 2010). Soil fumigation with fumigants such as Metam sodium has been recommended, though the efficacy is highly influenced by soil type, temperature, physical properties, pH, and water holding capacity (Woodward *et al.*, 2011). These conditions are difficult to achieve and regulate under smallholder rainfed systems. Again, soil fumigation is an expensive practice and exposes farmers to highly toxic compounds. For the safety of the applicator, full personal protective equipment should be put on as most of these fumigants are very toxic (Otieno, 2019). Biological control using bacterial antagonists (*Bacillus pumilus* (M1), *Pseudomonas fluorescens* Biotype F (DF37), and plant extracts (*Astragalus canadensis* L) have also been found effective in controlling Verticillium wilt (Uppal *et al.*, 2007). Some of these products are out in the market though likely to be expensive for most of the resource-constrained farmers.

2.2.5. Bacterial Wilt (*Ralstonia solanacearum*)

Bacterial wilt is a soil-borne disease which can spread by water, farm tools, infected seeds, previously infested crops residue, and volunteer potato crops. When attacked, the whole plant wilts and dries up, tubers get brown-black stain and rot, (hence reduced market quantity and quality). Yield losses of between 50-100% have been estimated and reported in the region (Muthoni *et al.*, 2012; Mwankemwa, 2015).

The pathogen has common host plants such as chili, tomato, tobacco, and eggplant, as well as several species of weeds that are commonly found in farmer fields. Management of this disease using available agrochemicals is difficult. However, farmers should be encouraged to use disease-free planting material of tolerant varieties and select fields that are free from bacterial wilt for crop production (Muthoni *et al.*, 2012). During rotation, cabbage/cauliflower should come immediately before planting potatoes due to their capacity to significantly reduce the pathogen (Larkin *et al.*, 2011).

2.2.6. Viral Disease (Leaf Roll Virus, Virus Y, and Potato Mosaic Virus)

These potato virus diseases have been reported across potato producing zones in the region (Okeyo *et al.*, 2019). The Leaf roll, Virus Y and Mosaic virus have been reported to cause up to 90, 80 and 40%, respectively, reduction on yield from cultivated plants (*cipotato.org*; Kaniewski *et al.*, 1990). Yield losses of up to 100% have also been quoted in the region (Chiunga, 2013).

There are no clear chemicals that directly control viral diseases in potatoes; however, management could be achieved through the selection of disease-free fields and planting of disease-free and certified seeds from tolerant varieties (Okeyo *et al.*, 2019). Management of vectors, such as whiteflies, aphids, and thrips through judicious use of selective pesticides could help (refer to the section under potato pests for better control of these vectors).

3. Conclusions

Potatoes are attacked by numerous pests and diseases in the farmer fields with high potential to cause low to high yield losses. The direct and indirect nature of impacts and the ability to attack at the fields and stores make potato tuber moth the most important pest in the region. Also, the capacity of pathogens to have a wide range of host plants and live in the soil make it difficult and unstainable to control diseases such as Late blight, Bacterial wilt, and Verticillium wilt. For farmers to sustainably manage these constraints, control must begin right from the selection of appropriate field and planting materials- all the must be free from pest and disease. However, land subdivision due to the high population growth rate is threatening the capacity of the farmers to select fields and rotate potato crops as farms become limited. Proper soil and nutrient management is important as the crops' tolerance levels are increased with better nutrition. Chemical application should be done with much care to avoid pollution and effect on beneficial insects that would otherwise cause ecological imbalance. Again, most of the farm chemicals are toxic to farmers and should be applied with maximum protection.

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