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Integrated Pest Management of Potato (*Solanum tuberosum L*)

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Abstract

Potato is one of the major crops of the world like rice, wheat, and maize. It has inherent qualities that give it a competitive edge over the leading food crops like the production of more protein and carbohydrates, vitamins, and minerals. Having many desirable characteristics, however, it is severely affected by numerous insect pests and diseases. There this review is mainly on the identification of pests and diseases of this major crop and to find their solution.

Keywords: Potato; Pests; Disease; IPM

Introduction

Potato *(Solanum tuberosum L.)* is the fourth major crop in the world after rice, wheat, and maize. Some inherent qualities give the potato a competitive edge over the leading food crops. It can produce more protein and carbohydrates per unit area than cereals and some leguminous crops like soybeans (Crowell et al., 2008). In addition to energy and quality protein, it also provides a substantial amount of vitamins and minerals. Scott et al. (2000), potato is the most important crop in developing countries and its production is expanding more rapidly than that of most other crops. As a result of this, it is becoming an increasingly important source of rural employment, income, and food for growing populations. Potato is regarded as a high-potential food security crop because of its ability to provide a high yield of high-quality product per unit input with a shorter crop cycle (mostly < 120 days) than major cereal crops like maize [1].

Recently the price of cereals strongly increased worldwide and in Ethiopia, the price subsequently stabilized at a high level, whereas the price of roots and tubers remained relatively low during the entire food crisis. This shows that there is room for added value in the chain of tuber crops. The main reason associated with this underutilization of potatoes is the narrow genetic base of the early introductions and the traditional view towards potatoes as poor man's food and also most of the people use cereals as staple food. In addition to this, the lack of high-yielding and disease-resistant improved potato varieties, problems of pests and disease are also the causes of the underutilization of potatoes in Ethiopia (Gebremedhin et al., 2008) [2].

Potatoes are attacked by a wide range of insect pests and diseases. Diseases like the late blight of potatoes, bacterial wilt, powdery mildew, ring rot, root-knot, skin spots, and leaks affect potatoes. Insect pests that affect potatoes include insect pests that attack foliage (potato leafhopper, Elateridae), insect pests that attack tuber, insect pests that attack both foliage and tuber (potato tuber moth, black cutworm), and insects that are important mainly by transmitting viral diseases (green peach aphid) [3]. For this case the application of integrated pest management (IPM) is important. IPM focuses on the long-term prevention of diseases and pests or their damage by managing the ecosystem. IPM focuses on taking actions to keep pests from becoming a problem, such as by growing a healthy crop that can withstand pest attacks, using disease-resistant plants, or caulking cracks to keep insects or rodents from entering a building using natural enemies and different cultural controls. Rather than simply eliminating the pests that we see right now, using IPM means we'll look at environmental factors that affect the pest and its ability to thrive. Based on this information, IPM creates conditions that are unfavorable for the pest and environmentally friendly. This review paper is aimed at major pests, disease description, biology, damage, host range on potatoes, and their integrated pest management (IPM) [4].

Major pests and diseases of potato

Common insect pests

Colorado potato beetle (Leptinotarsa decemlineata)

Pest description

The Colorado Potato Beetle (CPB) is a yellow and black striped beetle, about 1.3 cm long and 0.6 cm wide. They can be found in almost all U.S. potato regions. Larvae are reddish orange, with two rows of black spots on each side. Orange egg clusters are found mainly on the undersides of leaves, mostly in the top third of the plant. Eggs resemble ladybug eggs.

Biology

Pupation and overwintering occur in the soil. Adults emerge from the soil to lay eggs in the spring. Depending on the region, this insect may have three generations in a season. Adult beetles spend the winter buried 10-25 cm in the soil and emerge in the spring just as the first volunteer potatoes appear. Recently emerged beetles either mate close to the overwintering sites or fly to new potato fields to find a mate. Usually, first infestations occur around field margins. Eggs are deposited on potato foliage in masses. CPB eggs resemble lady beetle eggs. Larvae pass through four life stages and then burrow into the soil to pupate.

Damage

This beetle can cause complete defoliation and nearly complete crop loss if allowed to reproduce unchecked. Both larvae and adults feed on potato foliage throughout the season.

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Hosts

Potatoes are the preferred host for the Colorado potato beetle, but it may feed and survive on several other plants in the family Solanaceae, including belladonna, common nightshade, eggplant, ground cherry, henbane, horse-nettle, pepper (rarely), tobacco, thorn apple, tomato, and, its first recorded host plant, buffalo-bur. The Colorado potato beetle has displayed an ability to adjust its host range to locally abundant Solanum species. Colorado potato beetles also feed on non-solanaceous plants, but this is rare and these plants should not be considered normal hosts [5].

Management Tactics

Cultural control

Colorado potato beetle populations can be reduced through the use of relatively common cultural practices such as crop rotation, manipulation of planting time and crop varieties, use of mulches, cover and trap crops (Hough-Goldstein et al., 1993). Trap crops may be used to attract beetles away from the main crop. It has been shown to intercept both overwintered beetles colonizing a field in the spring as well as the beetles moving away from senescing potatoes late in the season (Hoy et al., 1996).

Biological control

Several predatory and parasitic arthropods attack the Colorado potato beetle (Hough-Goldstein et al., 1993). The ladybird beetle Coleomegilla maculata consumes eggs and small larvae (Groden et al., 1990; Hazzard et al., 1991). Predaceous stink bugs Perillus bioculatus and Podisus maculiventris attack beetle larvae [6].

Physical control

Handpicking, especially in small gardens, Drops adults and larvae in a pail filled with soapy water, and removing or crushing the yellowish orange eggs on the underside of leaves is effective.

Chemical control

Insecticides are commonly used to control populations of Colorado potato beetle, but resistance to insecticides develops rapidly. Chemicals like Pounce (permethrin), Guthion (azinphos-methyl), Thiodan (endosulfan), and Admire (imidacloprid) control at acceptable levels; however they develop some resistance toward Sevin (carbaryl) and Malathion (malathion).

Wireworms (Conoderus rudis)

Pest description

Wireworms are the larval stage of click beetles. Adult click beetles are slender hard-shelled insects. They range in color from chocolate to dark brown and from about 0.8 – 1.9 cm long, depending on species. Click beetles get their name from their ability to snap a spine on their thorax that produces a clicking sound and allows them to jump in the air when distressed or disturbed. All beetles in the Elateridae family have this ability. This technique is used to avoid predation or to get back on their feet after falling on their backs. Depending on the species, each female after mating lays an average of 80 eggs, singly or in small clusters in the soil. Immature stages have a hardened and shiny shell and very few hairs. They have three body regions with a distinct head, a thorax with 3 pairs of legs, and a segmented abdomen with a tail-end (Jensen et al., 2011). Characteristics of the tail-end serve for identification purposes. Depending on species and age, wireworm larvae range from about 2 mm after hatching to 4 cm long or more a maturity. Wireworm pupae are first white, but later change to reddish-brown; they pupae in the soil [7].

Biology

Adult click beetles emerge from pupae in the soil from late spring through late summer. In the Pacific Northwest, wireworms overwinter as larvae or adults. They can have up to a 7-year life cycle from egg to adult. Adults can fly but usually remain in the areas where they developed as larvae. Eggs are laid in grassland or in cereal crops where larvae feed on grass roots and overwinter in the soil. Females tend to lay eggs in grassy areas. Larvae can live from 2-5 years in the soil, depending on the species. They require several years to mature and can overwinter at a depth of 30-100 cm or more in the soil, only to return near the surface in spring to resume feeding when soil temperatures exceed 50°F (10°C). Later in the season when temperatures reach 80°F (26.6°C) and above, the larvae tend to move deeper than 15 cm into the soil to escape the heat (Schreiber et al.,2010) [8].

Damage

Wireworms can cause damage to potatoes by feeding upon potato seed pieces and sprouts in the spring, facilitating infection by pathogens or other insect pests. The latter damage can result in a reduction in yield and/or rejection of the entire crop. Wireworms tend to be most damaging in potatoes that follow corn or small grains (wheat, barley) and on the ground just entering cultivation. Wireworms damage potatoes both near planting time (damage to seed pieces) and during the growing season (damage to developing tubers). They can also be a problem at harvest and before entering storage [9].

Hosts

Potatoes, corn, wheat, and grass are the main hosts for several species of wireworm's beans, carrots, peas, and other annual crops may be infested, while melons, beetroots, and strawberry fruits are affected less frequently.

Management Tactics

Cultural control: where possible, avoid growing potatoes in wireworm-infested fields. Plan and utilise a range of risk assessment methods such as pheromone and bait trapping as well as soil sampling to confirm the status of each field. In arable rotations, plough-based cultivation may help to reduce wireworm populations.

Biological control: Birds and predatory beetles prey on wireworm larvae. Entomopathogenic fungi (Beauveria and Materhizium spp) also attack wireworms. According to Ericsson et al (2007), the combination of Materhizium anisopliae and spinosad killed more wireworms than their additive effect. Moreover, there is a significant reduction in the wireworm population after treatment with Beauveria bassina (Ester and Huiting, 2007).

Host resistance

Potato varieties like AC9521, VC1009, Cherry Red, Ozette, Maris piper, Yukon Gold, and King Edward have resistance to wireworms (Johnson 2008) [10].

Chemical Control: to be effective, insecticides for the control of wireworms need to be incorporated into the soil at planting and remain active until late in the life of the crop. Initially, organochlorines such as aldrin and lindane were used effectively, but environmental hazards meant that these have been replaced by the organophosphorus insecticides ethoprophos and fosthiazate. However, organophosphorous insecticides are effective at controlling wireworms they do not prevent all damage to potato tubers by this pest.

Some insecticides from different chemical groups, including pyrethroids and neonicotinoids, have activity against wireworms. These are available as seed treatments. For sugar beet, cereals, and oilseed rape in the UK. The use of these products on the appropriate crops in the rotation will help reduce the wireworm population size.

Potato tuber moth (Phthorimaea operculella)

Description

Potato tuber moth (PTM) has four stages: egg, larva, pupa, and adult. Adults have a narrow, silver-gray body with grayish-brown wings patterned with small dark spots (pictured). The body length is around a third of an inch and the wing span of an inch (2.54 cm). It is mostly nocturnal and attracted to light. They are poor fliers. Eggs are oval, smooth, and yellow, laid alone or in clusters on leaves or near eyes on infested tubers. Larvae are gray, cream, or pale green with a dark brown head about half to three-quarter inch long in the final instars. Pupae are yellow or rust-colored and pupation occurs among dead leaves or debris, in soil, or on stored tubers [11].

Damages

Potato tuber moth (PTM), is a caterpillar insect pest that attacks potato plants in fields and storage causing great damage to foliage and tubers (Ibrahim et al., 2001) and it is one of the pests that causes the most extensive damage in the field and storage of potatoes, especially in warm dry climates.

On leaves, damage is caused by the tunneling of the caterpillars between the upper and lower epidermis of the leaves. The mines have a blotchy appearance and are often associated with brown and dying bits of tissue. As the caterpillars increase in size, they tend to mine near the leaf base, and even down into the petiole and stem, which becomes blackened. In young plants, this may result in withered and dying shoots. In potatoes, towards the end of the season, the caterpillars move down the plant towards the exposed tubers in the soil (Binyam, 2015).

Hosts

Potato tubeworms are mainly associated with potatoes; however, they have been observed feeding on other plants such as tomatoes, eggplants (Solanum melongena L.), peppers (Capsicum spp.), tobacco, and wild solanaceous plants like Jimson weed or datura (Datura stramonium L.) (Alvarez et al.,2005) [12].

Management Tactics

Cultural controls

- Keeping potatoes well hilled so there are always at least 5 cm of soil over the tubers
- Cultivating or irrigating to prevent deep cracks in the soil
- Planting fall potatoes as far as possible from the location of the spring crop
- Destroying cull potatoes, perhaps by feeding them to livestock
- Eradicating volunteer plants early in spring
- Harvesting potatoes soon after maturity and removing them from the field immediately after digging.

Host resistance

In field experiments, glandular trichome clones showed a high level of resistance to potato pests, including PTM (Mohammed, 2003).

Biological controls

Natural enemies of potato tuber moth can be used as a part of an IPM program. The use of Beauveria bassiana and Materhizium anisopliae is considered effective management of PTM in potatoes and using the higher fungal concentration is also advantageous. In general, as the concentration levels of fungus increased, the number of larvae and the damage they caused on leaves significantly decreased (Tekalign et al., 2015). The parasitoids, Copidosoma koehleri and Bracon gelechiae have been used with some success in South America and Australia, respectively (Alvarez et al., 2005) [13].

Chemical controls

A natural chemical that can be used to help keep potato tuber moth populations in check is a Bacillus thuringiensis formulation. Most insecticides that contain carbomates, pyrethroids, or organophosphates can reduce adult populations. Typically, application is most successful when done at dusk when the adults are active. These chemicals will not have much of an effect on the larvae, making multiple applications often necessary. Other insecticides that are effective on the tuber moth larvae: indoxacarb, novaluron, and spinosad (www.field guide potato tuber worm).

Common Diseases

Bacterial Wilt (Ralstonia solanacearum)

Description

R. solanacearum is a Gram-negative bacterium with rod-shaped cells, 0.5-1.5 μm in length, with a single, polar flagellum. Gram-negative rods with a polar tuft of flagella, nonfluorescent but diffusible brown pigment often produced (EPPO, 2004). On the general nutrient media, virulent isolates of R. solanacearum develop pearly cream-white, flat, irregular, and fluidal colonies often with characteristic whorls in the center. Avirulent forms of R. solanacearum form small, round, non-fluidal, butyrous colonies which are entirely cream-white. It is serious in the irrigation application of water sources (Janse, 2012).

Biology

Specific strains pathogenic for certain hosts may have evolved only in certain parts of the world and are not found elsewhere or, these hosts may only be susceptible where several environmental factors conducive to disease expression coincide, such as temperature regime, rainfall, soil type, inoculum potential, and other soil biological factors such as nematode populations. Until isolates from different hosts can be directly compared under standard conditions that use infectivity titration as a measure of the resistance of the host and virulence of the pathogen this discrepancy will not be understood [14].

Damages

In the early stages, the disease causes rapid wilting of the youngest leaves at the end of the branches during the hottest time of the day (EPPO, 2004). At this stage, only one or half a leaflet may wilt, and plants may appear to recover at night when the temperatures are lower (Champoiseau et al., 2009). Infected stem vascular bundles may become visible as long, narrow, dark-brown streaks, and the stem may also collapse in young potato plants (Champoiseau, 2008) [15].

Hosts

Bacterial wilt attacks more than 200 species. These include economically important hosts such as tobacco, potato, tomato, eggplant, pepper, banana, peanut, and beans. Thorn apple and nightshade are two common weed hosts that are attacked by the disease.

Management Tactics

Cultural control

Phytosanitation and cultural practices are the most widely used practices for controlling bacterial wilt in the field (Champoiseau et al., 2010). These practices can be effective in regions where bacterial wilt is endemic, or in locations where it is present but not yet established [16].

Biological Control

Among biological control agents, several soil bacteria and plant growth-promoting rhizobacteria (PGPR) are currently being investigated for their role in the control of R3bv2A (Champoiseau et al., 2010).

Henok et al., (2007) evaluate Ethiopian isolates of Pseudomonas fluorescens as biocontrol agents against potato bacterial wilt caused by Ralstonia (Pseudomonas) solanacearum. According to Henok et al., (2007) three isolates of Pseudomonas fluorescens i.e., PfS2, PfWt3, and PfW1 showed inhibition against the growth of the pathogen [17].

Lemessa (2006) working on biochemical, pathological and genetic characterization of strains of Ralstonia solanacearum (Smith) from Ethiopia and biocontrol with bacterial antagonists found that the most effective strains (Pseudomonas fluorescent APF1 and Bacillus subtlis B2G) consistently reduced wilt diseases and increased plant weight significantly [18].

Chemical Control

The most commonly used chemical treatment has been fumigation of contaminated soil/portions of the farm with methyl bromide (Champoiseau et al., 2010). This is a very expensive and tedious exercise and cannot be used in large areas. In addition, methyl bromide has been banned in most parts of the world and is being phased out. The other product commonly used at the field level is sodium hypochlorite; it is appropriate for spot treatment of the holes left behind after rogueing of the wilting plants, and for general field sanitation but the use of sodium hypochlorite is expensive and tedious (Kaguongo et al., 2008) [19].

Late Blight of potato (Phytophthora infestans)

Description

Late blight is a plant disease that mainly attacks potatoes. Late blight was a factor in the Irish potato famine in the 1850s, during which millions of people in Ireland starved or were forced to emigrate. Entire potato crops rotted in the field or storage because of late blight infection. Late blight is caused by an oomycete pathogen that survives from one season to the next in infected potato tubers [20]. This organism is well known for its ability to produce millions of spores from infected plants under the wet weather conditions that favor the disease (www.late blight). Early in the season, the disease can be introduced into a field or garden on infected seed potatoes, from volunteer plants growing from diseased potatoes that were not harvested last season, from infected potatoes in cull piles (rejected potatoes), compost piles, or infected tomato transplants brought into the area. Spores produced on infected potatoes and tomatoes can travel through the air, land on infected plants, and if the weather is sufficiently wet, cause new infections. Spores can also be washed through the soil to infect potato tubers, which may rot before harvest, or later in storage [21].

Biology

The life cycle can be completed on potato foliage in about five days under ideal conditions. Sporangia develop on the leaves, spreading through the crop when temperatures are above 10 °C (50 °F) and humidity is over 75%-80% for 2 days or more (Nowicki, 2013). Rain can wash spores into the soil where they infect young tubers, and the spores can also travel long distances in the wind. The early stages of blight are easily missed. Symptoms include the appearance of dark blotches on leaf tips and plant stems. White mold will appear under the leaves in humid conditions and the whole plant may quickly collapse. Infected tubers develop grey or dark patches that are reddish brown beneath the skin, and quickly decay to a foul-smelling mush caused by the infestation of secondary soft bacterial rots [22].

Damage

Late blight of potato causes black/brown lesions on leaves and stems. In humid conditions, Phytophthora infestans produces sporangia and sporangiophores on the surface of infected tissue. This sporulation results in a visible white growth at the leading edge of lesions on the abaxial (lower) surfaces of leaves. As many lesions accumulate, the entire plant can be destroyed in only a few days after the first lesions are observed. Potato tubers become infected in the field when sporangia are washed from the foliage into the soil. Infected tuber tissues are copper brown, reddish, or purplish [23-25].

Hosts

Potato, tomato, eggplant, and other Solanaceae.

Management Tactics

Cultural Control

Use proper cultural practices, including the following, as the first line of defense:

- Increase spacing of plants to reduce canopy density
- Promptly remove or destroy volunteer potatoes found in other crops grown in rotations or elsewhere
- Control weed hosts, such as hairy nightshade
- Use proper hilling to reduce infection in tubers
- Carefully manage irrigation to avoid increasing disease risk through prolonged periods of wetness
- Identify and destroy hot spots of infection in a field to reduce the production and spread of spores.

Biological control

The damage of late blight of potatoes is minimized using different biological agents like Trichoderma viride-ES1 and Pseudomonas fluorescens-Bak150 (Ephrem et al, 2011).

Host resistance

Planting resistant varieties will slow down (but not prevent) the development of late blight. Currently, Defender and Elba are the most resistant varieties of potato available. Potato varieties with moderate levels of resistance include Kennebec, Sebago, and Allegany (WWW, nysipm.cornell.edu) [26].

Chemical control

The disease is primarily controlled by the use of resistant cultivars and fungicide sprays (Namanda et al. 2004). However, concerns about the environment, public health, and fungicide resistance have stimulated efforts to reduce the amount of fungicide used in late blight management. In Ethiopia, farmers frequently apply fungicides to control late blight but the economic benefits accruing from the fungicide spray have not been established (Bekele and Hailu, 2001). Binyam et al. (2014a) also reported that reduced rates of Ridomil application resulted in better management of potato late blight with the highest marginal rate of return [27].

Conclusion

Potato is one of the major crops of the world like rice, wheat, and maize. It has inherent qualities that give it a competitive edge over the leading food crops like the production of more protein and carbohydrates, vitamins, and minerals. Having many desirable characteristics, however, it is severely affected by numerous insect pests and diseases. In the future, it is advisable to expand the application of different integrated pest management tactics since it focus on the long-term prevention of insect pests and diseases by managing the ecosystem and being environmentally friendly.

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Data availability: data openly available in a public in open access.

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