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7. Organic Approaches to Disease and Pest Management in Potato

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Abstract:

Potato (Solanum tuberosum L.) is a global staple crop, but it faces serious risks from diseases and pests that reduce output and quality. Organic techniques to disease and pest management are gaining popularity as environmentally benign alternatives to traditional chemical treatments. This research examines the efficacy of organic solutions for managing key potato diseases and pests, including cultural practices, biological management, and the use of organic pesticides. Crop rotation, intercropping, and the use of resistant varieties are all important cultural techniques for minimizing disease outbreaks and pest infestation. Biological control entails using natural predators, parasitoids, and microbial antagonists to reduce pest populations and disease pathogens. Organic pesticides generated from natural sources provide focused control while minimizing environmental effect. Additionally, including these strategies into a comprehensive pest management framework might improve their efficacy and sustainability. Case studies demonstrating successful organic management implementations in various countries demonstrate the effectiveness of these approaches. The review concludes that, while challenges remain, particularly in terms of scalability and consistency, organic disease and pest management provides a viable path to sustainable potato production, in line with rising consumer demand for organically produced foods and environmental conservation goals. Further research and development are required to improve these technologies and promote their widespread use among potato producers.

Keywords:

Potato, Biological control, Organic pesticides, Resistant cultivars

7.1 Introduction:

India is the world's second-largest producer of potatoes, after China. Potato cultivation in India is spread across several states, with Uttar Pradesh, West Bengal, and Bihar contributing the most. Potato production in India has increased significantly in recent decades as a result of advances in agricultural practices, improved seed varieties, and better irrigation methods. Potatoes are an important crop in India's agriculture sector, ensuring food security and providing a source of income for millions of farmers. Potatoes' versatility, combined with their nutritional benefits, make them a staple in Indian cuisine and an important component of the agricultural industry (Balakrishnan *et al*., 2005; Gwinn *et al*., 2010).

All species of plants, wild and cultivated alike, are susceptible to disease. The occurrence and prevalence of plant diseases vary from season to season, depending on the presence of the pathogen, environmental conditions, and the crops and varieties grown. Some plant varieties are particularly subject to outbreaks of diseases; others are more resistant to them. Plant diseases create challenging problems in commercial agriculture and pose real economic threats to organic farming systems (Pant *et al.*, 2023).

The long-term use of synthetic chemicals to manage pests has a number of disadvantages which cause environmental pollution, phytotoxicity, ground water contamination and adversely affect the soil and its biotic environment.

For this the organic approaches to disease management in plants emphasize prevention, resilience, and ecological balance to combat pathogens while minimizing reliance on synthetic chemicals. In agriculture, organic disease management involves practices such as crop rotation, intercropping, and the use of cover crops to improve soil health and reduce disease pressure.

Additionally, natural substances like compost teas, plant extracts, and beneficial microorganisms are employed to enhance plant immunity and suppress pathogen growth. Companion planting involves intercropping plants that naturally repel pests or attract beneficial insects, creating a more diverse and balanced ecosystem that can deter diseases (Baker, T. C. 2008; Pandey *et al*., 2022 a).

Another organic method is the use of resistant plant varieties bred through traditional methods or genetic engineering to withstand specific diseases. Biological control involves introducing beneficial organisms like predatory insects or microbes that target plant pathogens, thereby reducing their populations. Soil management practices such as maintaining healthy soil structure and fertility promote vigorous plant growth, making them less susceptible to diseases (Maurya *et al*., 2023 a; Pandey *et al*., 2022 b).

Furthermore, cultural practices like proper irrigation, sanitation, and timely removal of infected plant material help prevent disease spread. Organic farmers also utilize natural fungicides and bactericides derived from plants, minerals, or beneficial microbes to manage diseases when necessary, adhering to organic certification standards. Overall, organic approaches to disease management prioritize ecological harmony, long-term sustainability, and minimal environmental impact while safeguarding plant health and crop productivity. *Rhizoctonia solani* and Fusarium species, leading to healthier crops and improved yields (Weller, 2007; Maurya *et al*, (2023 b). Similarly, introducing predatory insects like lady beetles can help control aphid populations, a common pest in potato fields (Collier & Van Steenwyk, 2004).

7.2 What Organisms Cause Disease?

1. Fungi
2. Bacteria
3. Viruses
4. Nematodes

Symptoms Caused by All These Organisms?

1. **Fungi:** Fungi are the most abundant group of plant pathogens. These multicellular organisms are typically microscopic. The "body" of a fungus is composed of filament-like threads called "hyphae." Masses of hyphae are called "mycelia." Fungi are typically spread by wind, rain, soil, mechanical means and infected plant material and cause spots, lesions, blights, yellowing of leaves, wilts, cankers, rots, fruiting bodies, mildews, molds, leaf spots, root rots, cankers, and blotches (Maurya *et al*., 2023; c).
2. **Bacteria:** Bacteria are microscopic organisms typically composed of single cells. Due to their small size, a high-magnification microscope is required to observe bacteria. Bacteria are capable of rapid reproduction through a process known as binary fission and are typically spread by rain, mechanical means, planting material, vectors (ex. bacterial wilt of cucurbits spread by cucumber beetle) and cause water-soaking, spots, wilts, rots, blights, cankers, exudates, galls, yellowing, leaf spots, watery blotches, wilting.
3. **Viruses:** Virus is a strand of DNA or RNA, consisting of a nucleic acid wrapped in a thin coat of protein. Once viruses enter host cells, they "hijack" plants and "instruct" cells to produce more virus particles. Viruses are spread by mechanical means, vectors and in plant material and cause mottling, leaf and stem distortions, mosaic patterns, rings and stunting. Viruses cause interesting symptoms, some are beautiful (Ravishankar *et al.*, 2023).
4. **Nematodes:** Plant parasitic nematodes are microscopic roundworms that primarily infect roots, but a few occur in foliar portions of plants. While there are many species of nematodes, only a few are known to parasitize plants. Nematodes reproduce via eggs that result from either the mating of a male or a female or by the female alone. Nematodes are spread by soil on equipment or workers boots or on infected plant material and cause wilting, stunting, and yellowing of entire plants. This is because the roots of the plant are infected, and the plant is starving or thirsty.

7.3 Control Methods for These Things:

The National Organic Program has a hierarchical approach to pest management starting with System-based cultural practices then Mechanical and Physical Practices and finally Material-based (chemical, botanical, elemental) practices.

A. Cultural Control of Crop Disease:

Cultural control is the first line of defense, and it aims to prevent contact with the pathogen, to create environmental conditions unfavorable to the pathogen, or to reduce the amount of pathogen inoculums available to the infected crop plants.

Cultural control is just a modification or manipulation of the environment to the disfavor of pests by disrupting their reproductive cycles, eliminating their foods, destroying their weed hosts or making the environment more favorable for predators, parasitoids and antagonists. The important cultural practices suitable for organic production to reduce the severity of insects, pests and diseases are as follows.

1. **Tillage Operation:** Deeply burying infested crop debris and pathogen survival structures by moldboard plowing reduces disease incidence. For this to work, the residue must be buried deeply enough that it is not pulled back up during seedbed preparation and cultivation. Burying diseased material is especially useful against pathogens that produce sclerotia and those that infect only aboveground plant tissue.
2. **Field and Plant Sanitation:** Regular removal of weeds, pest-affected plant parts, crop stubbles and their destruction will eliminate the sources of infestation of the diseases and pests. Wash soils off of farm equipment, including brushing off soil particles from shoes. These practices are especially important to prevent movement of soil borne pathogens such *Sclerotinia sclerotiorum* (causal agent of White mold), *Phytophthora capsici*, *Verticillium dalhiae*, and different species of Fusarium. A power washer is an important piece of equipment in the battle against these diseases.
3. **Crop Rotation:** Some pathogens that because diseases survive in the soil from year to year in one form or the other, usually as sclerotic, spores, or hyphae. Continuously cropping the same crop builds up the population levels of any soil borne pathogen of that crop that may be present. Growing of a non-host crop after a host crop of the pest will break the breeding cycle of pest species and reduce their population. Likewise, crop rotation prevents the buildup of plant pathogen in soil.
4. **Growing of Resistant Cultivar:** Certain varieties of crops are less damage or less infested than other by insects. The resistant varieties have physical and physiological features, which enable to avoid pest attacks. The use of resistant cultivars is one of the most important and economical components of an integrated disease management program. Resistant cultivars offer one of the most successful approaches to the control of pathogens of many crops, especially those diseases that cannot be controlled by other means. The term resistance usually describes the plant host's ability to suppress or retard the activity and progress of a pathogenic agent, which results in the absence or reduction of symptoms (Balakrishnan *et al*., 2005; Gwinn *et al*., 2010).
5. **Adjusting Time of Sowing:** The simultaneous sowing of crops in a locality helps in reducing pest damage. Alternating the time of planting to avoid high levels of pathogen inoculum or conditions conducive for development of a particular disease can lead to reduced severity of some crop diseases. For example, early-planted fields of soybeans may have a greater incidence of seedling blights caused by *Fusarium solani* and *Pythium* if planted early in cool and wet soils. The incidence of these two diseases can be reduced by delaying planting until the soil warms up.
6. **Site Selection:** A grower can incur significant losses if susceptible crops planted in fields known for having a history of soil pathogens. Plant-pathogenic fungi such as *Armillaria*, *Fusarium* (the wilt-causing species), *Plasmodiophora*, *Sclerotium*, and *Verticillium* are true soil inhabitants and will persist in soil for many years, even in the absence of a plant host. Soilborne fungi such as *Phytophthora*, *Pythium*, and *Rhizoctonia* often are much more widespread, so site selection might be less of an option in avoiding these pathogens. If possible, avoid planting crops in low-lying, wet areas given the higher incidence of soilborne diseases.
7. **Density of Crop:** Crop density can exert considerable influence over disease incidence due to the ease with which the pathogen inoculum can be transferred closely between closely spaced plants. In closely planted crops, temperatures are more uniform, humidity is higher, and foliage is wetter for longer periods of the day, all of which provides favorable conditions for pathogen infection and subsequent development.

Diseases such as downy mildew and Sclerotinia stem rot (white mold) are greatly, affected by high humidity.

8. **Removal and Destruction of Crop Residues:** Crop residues provide suitable substrates for many pathogens. Physically removing and destroying (e.g., burning, burying, etc.) crop residues are important cultural control practice performed during intercrop periods. The effect of destroying crop residues on particular pathogens depends on the type of crop (annual, perennial, or harvested product), the extent of the cropping area and the survival mechanisms and host ranges of the target pathogens.
9. **Water Management:** Flooding of field whenever possible; kills root grubs, termites and soil borne plant pathogens. Draining of water for a few days in paddy fields suppress brown plant hopper population.

B. Mechanical Methods:

Mechanical methods of disease and pest management in organic farming involve physical interventions to control pests and diseases without chemicals. These include soil solarization, hot water treatment, pruning, thinning, trap crops, flame weeding and physical removal. All these methods are eco-friendly, preserving beneficial organisms and maintaining soil health.

1. **Soil Solarization:** Soil solarization is a hydrothermal process for controlling soil borne diseases in soil prior to planting crops. Effective control of soil borne plant pathogens (plant parasitic nematodes, fungi, and some bacteria) is a serious challenge to organic farmers. It involves mulching of soil with clear plastic films so as to trap the solar heat in the surface soil. The resultant temperature increase would be lethal to soil pathogens, nematodes and weeds. This method can be use where air temperature goes up to 45^0C during summer months. It is efficient where bright sun light is available for about 4-6 weeks.
2. **Hot Water Treatment:** Hot water treatment of own seed to prevent seed borne diseases such as black rot, black leg, black spot and ring spot of crucifers is recommended. This treatment helps reduce the seed-borne pathogens such as *Alternaria* spp., *Colletotrichum* spp., *Phoma* spp., *Septoria* spp., and bacterial pathogens (*Pseudomonas* spp., and *Xanthomonas* spp). However, specified temperature and time interval must be strictly followed in order to maintain seed viability. Use a good thermometer or better ask for assistance from qualified personnel from your local extension office. Hot-water seed treatment works best for small seed. It is not as effective for large or extremely fragile seed, pelleted seed, primed seed (i.e., seed treated to speed germination), fungicide-treated seed, and old seed. To most effectively hot-water treat seed, use a water bath (in home cooking often referred to as a “water oven”) with precise temperature and timing control. For potato tubers heat treatment of 10 min in water at 55°C was used. The same treatment of naturally or artificially contaminated seed tubers gave complete absence of blackleg infection in the field and decreased the amounts of powdery scab (*Spongospora subterranea*) and black scurf (*Rhizoctonia solani*) on progeny tubers.
3. **Pruning:** Pruning is an effective disease management tool that controls plant diseases by removing infected or dead plant parts, thereby reducing the spread of pathogens. It improves air circulation and sunlight penetration within the canopy, which creates unfavorable conditions for fungal and bacterial. Pruning also eliminates potential

disease vectors and habitats for pests and it can significantly reduce the incidence and severity of diseases in organic farming.

4. **Thinning:** In plant disease control the adequate spacing of plants improves air circulation and sunlight penetration, reducing humidity and creating unfavorable conditions for pathogens. This practice helps foliage dry faster after rain or dew, preventing fungal and bacterial infections. By decreasing plant density, thinning minimizes physical contact between plants, lowering the risk of disease transmission. It also enhances access for monitoring and applying targeted organic treatments. Overall, thinning promotes a healthier growing environment, strengthening plants' natural defenses and making disease outbreaks less likely, thus playing a crucial role in integrated pest management in organic farming.
5. **Trap Crops:** A trap crop is a plant that attracts agricultural pests, usually insects, away from main crops can help reduce disease spread by vectors. This form of companion planting can save a target crop from decimation by pests without the use of artificial pesticides. By concentrating pests on the trap crops, farmers can manage and control infestations more effectively, often removing or treating the trap crops to reduce pest populations. This method decreases the pest pressure on the main crop, lowering the likelihood of disease transmission.
6. **Flame Weeding:** Flame weeding is the killing of weeds with intense heat produced by a fuel-burning device, either hand-held or tractor-mounted. Flame weeding usually relies on propane gas burners to produce a carefully controlled and directed flame that briefly passes over the weeds. Flame weeding controls plant disease by using intense heat to kill weed seedlings and plant residues that can harbor pathogens. The process sterilizes the soil surface, reducing the presence of disease-causing organisms and weed hosts that might spread infections.
7. **Physical Removal:** Physical removal of plants controls disease by directly eliminating infected or diseased plant parts to prevent the spread of pathogens. This proactive measure prevents pathogens from spreading to healthy tissues or neighboring plants. By removing symptomatic foliage or entire plants, farmers interrupt the disease cycle, resultant reducing the pathogen load. Additionally, physical removal minimizes the risk of secondary infections and limits the buildup of inoculum. Coupled with proper sanitation practices, such as disposing of removed plant material away from fields, this approach helps maintain a clean and disease-free growing environment. Ultimately, physical removal is a fundamental strategy in organic farming for effective disease management.

C. Biological Methods:

Biological control means ‘The utilization of any living organisms for the control of insect-pests, diseases and weeds. This means uses of any biotic agent for minimizing the pest population either directly or indirectly.

Conservation of these biotic agents in the field or multiplying in the laboratory and releasing in the fields is called biological control (John *et al.*, 2019 a). Biological methods of disease and pest management under organic mode of production involve natural predators, parasites, and pathogens to control pests and diseases (John *et al*., 2019 b). These include:

1. Predators:

The predators are feeding several of the insect-pests during their life cycle and hold a key role in minimizing pest population under field conditions. The common predators are birds, spiders, dragonflies, ladybird beetles, ground beetles, ants, chrysoperla etc; are helps to control sucking pests, pod borer eggs and larvae. Predators in biological control are natural enemies that feed on pest organisms, helping to manage pest populations in organic farming. Key examples include:

a. **Chrysoperla:** Control to Soft body insects like aphids, White hay, leaf hoppers, thrips etc.
b. **Lady bird beetle:** Effective against Aphids, mealy bugs, mites and other soft-bodied insects.
c. **Lacewings:** Their larvae, known as aphid lions, prey on aphids, thrips, and caterpillars.
d. **Predatory Beetles:** Ground beetles and rove beetles target a variety of pests including slugs, caterpillars and soil-dwelling larvae.
e. **Hoverflies:** Their larvae consume aphids, scales, and small caterpillars.
f. **Spiders:** Generalist predators that catch a wide range of insect pests in their webs.
g. **Parasitic Wasps:** Lay their eggs inside or on pest insects, with the developing larvae consuming the host.
h. **Birds:** Many bird species feed on insects, including caterpillars, beetles, and grasshoppers.
i. **Predatory Mites:** Control spider mites and other small arthropods.

These predators help maintain ecological balance and reduce the need for chemical interventions in organic farming.

2. Parasitoids:

These insects are always require passing at least one stage of their life cycle inside the host. The tiny adults of parasitoids search for the host eggs and parasitize them, i.e. they lay their own eggs within the egg of the pests. On hatching, the parasitoid larva feed on the embryonic content of egg. Thus, kill only one host insect during their life. However, due to their high multiplication rate they are of vital importance in the bio-control agents. After feeding on host body fluids and organs, most parasites leave their hosts to pupate or emerge as adults (Maurya *et al*., 2020). Key examples are:

a. **Trichogramma Wasps:** These tiny wasps parasitize the eggs of moths and butterflies, preventing the hatching of caterpillars.
b. **Aphidius Wasps:** These wasps target aphids, laying eggs inside them. The developing larvae consume the aphid from within.
c. **Encarsia Formosa:** Used against whiteflies, these wasps lay eggs inside whitefly nymphs, which are then killed as the wasp larvae develop.
d. **Cotesia Glomerata:** These parasitoid targets caterpillars, especially those of the cabbage white butterfly, by laying eggs inside them.
e. **Anagyrus Pseudococci:** Effective against mealybugs, these wasps parasitize and kill them by laying eggs inside.

f. **Diglyphus Isaea:** Targets leaf miners by parasitizing their larvae, thereby reducing leaf damage in crops.
g. **Eretmocerus Eremicus:** Used to control various whitefly species, this wasp lays eggs next to whitefly nymphs, with the larvae feeding on them.

These parasitoids provide targeted control of specific pests, reducing the need for chemical pesticides and supporting sustainable organic farming practices.

Crop	Pest	Parasitoids	Dosage/ha
Cotton	Boll warms	*Trichograma chilonis*	1,50,000
Sugarcane	Early shoot borer, stock borer	*Epiricania melanoleuca*	50,000
Paddy, Maize	stem borer	*T. japonicum*	50,000

3. Biological Chemicals: The pesticides derived from living organisms are bio pesticides. These products are more selective, eco-friendly and leave no toxic residues in the environment. The identification of natural chemicals opens new era of pest control. These chemicals do not kill the insects, but either attract, repel or modify their usual behaviour. Behaviour modifying chemicals which reduce matting frequency or release large numbers of sterile insects, control pests biologically by reducing their numbers (John *et al*., 2019; John *et al*., 2020).

Biochemical	Pests	Action
1. Nim oil	Grasshopper, leaf minor, white flies, scales, mealy bugs pod borer, moth etc.	Azadiractin acts as a repellent antifident (*Azadirecta indica*)
2. Nicotine sulphate	White flies, Aphids, Jassids, Helicoverpa	Nicotine sulphate acts as a contact poison and fumigant
3.Pyrethrum/ pyrethrins	Ants, aphids, flies, ticks	The trade name pyrenone is a contact poison act as pyrethroids
4. Garlic, Chilli, Ginger extract	Shoot borer, Fruit borer, Stem borer, Hairy caterpillar (on drum stick) and army worm of vegetable crops.	

4. Nematodes:

Insect-parasitic nematodes (also called entomopathogenic nematodes) are small, almost microscopic worms that attack and kill insects that live in moist habitats, especially water and damp soil (Simon *et al*., 2021; Maurya *et al*., 2018). Beneficial Nematodes are:

***Steinernema* spp.:** Targets pests like cutworms, root weevils, and corn earworms.

***Heterorhabditis* spp.:** Effective against beetle larvae, including Japanese beetles and rootworms.

5. Microbial Insecticides: These products are obtained from microorganisms such as bacterium, soil borne actinomytes and fungal pathogens. The insecticidal crystal proteins produced by the bacterium, *Bacillus thuringiensis kurstaki* are effective against lepidopterous pest species. These toxins are very specific in their action, easily biodegradable and being stomach poisons, safe for non-target organisms they are as follows.

No.	Bio control agent	Crop	Pest/ disease	Remarks
1.	*Trichoderma harzianum, Trichoderma viridae*	Tomato, chilli, Brinjal, G. nut	Root rot, stem rot, blight, damping-off, wilt, nematodes	Fungal antagonists, soil treatment
2.	*Pseudomonas florescenes*	Banana Tomato Potato Chilli	Wilt Wilt, white rot Tuber rot Fruit rot Die back	Sucker Treatment Soil treatment Seed treatment Seed & Seedling treatment
3.	*Bacillus thurengensis*	Cotton Cabbage, Tomato, Gram etc.	Lepidopterous pests	Foliar application
4.	*Verticillum lecanii*	Cotton, Vegetable crops	Aphid, whitefly	--"--
5.	*Beauveria bassiana*	Gram, Tobacco Cotton Tomato	Pod borer, cater pillar, thmps aphids, mealybugs	Spray application
6.	Nuclear polyhedrosis viruses (NPV) Granylosis Viruses (GV)	Chickpea, Maize, sunflower pigeon pea	*Heliothis spodoptera*	Spray the extraction of 250 crushed larve/ha

6. Mineral Insecticides: Sulphur is the oldest known pesticide & currently it is used. It can be used as dust, wettable powder, paste or liquid for control powdery mildews, rusts, leaf blight etc. Sulphur damage the plants, when it is applied in hot (above 900 F) and dry weather. Do not use sulphur where recently oil compound has been sprayed, it reacts with the oils to make a more phytotoxic combination.

7.4 Advantages of Biological Control:

1. Biological control is less costly and cheaper than any other methods,
2. Biocontrol agents give protection to the crop throughout the crop period,
3. Disease control is largely achieved by Largely by parasites and predators.
4. They are highly effective against specific plant diseases.
5. They do not cause toxicity to the plants.

6. Application of biocontrol agents is safer to the environment and to the person who applies them.
7. They multiply easily in the soil and leave no residual problem.
8. Biocontrol agents can eliminate pathogens from the site of infection,
9. Biocontrol agents not only control the disease but also enhance the root and plant growth by way of encouraging the beneficial soil microflora. It increases the crop yield also.
10. Biocontrol agents are very easy to handle and apply to the target,
11. Biocontrol agents can be combined with bio fertilizers,
12. They are easy to manufacture.

7.5 Disadvantages of Biological Control:

Although biological control is advantageous in many aspects, it has the following disadvantages:

1. Biocontrol agents can only be used against specific diseases.
2. They are less effective than the fungicides.
3. Biocontrol agents have slow effect in the control of plant diseases.
4. At present, only few biocontrol agents are available for use and are available only in few places,
5. They are unavailable in larger quantities at present.
6. This method is only a preventive measure and not a curative measure.
7. Biocontrol agents should be multiplied and supplied without contamination, and this requires skilled persons.
8. The shelf life of biocontrol agents is short. Antagonists, *Trichoderma viride* is viable for four months and *Pseudomonas fluorescens* is viable for 3 months only.
9. The required amount of population of biocontrol agents should be checked at periodical interval and should be maintained at required level for effective use.
10. The efficiency of biocontrol agents is mainly decided by environmental conditions.
11. A biocontrol agent under certain circumstances may become a pathogen.

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