8 Improved Practices Through Biological Means for Sustainable Potato Production

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Abstract

Potato (*Solanum tuberosum* L.) is the most important non-grain food crop in the world; ranking fourth in terms of total production. It is grown in around 150 countries spread across both temperate and tropical regions at elevations up to 4000 m. Globally, production of potato amounted to approximately 376.83 metric tons. In India, West Bengal is the largest potato producing state. Potato holds a great potential as food for ever increasing population. Potential yields of potato are determined by the characteristics of the crop and various biotic and abiotic factors. Among biotic factors, pathogens like fungal, bacterial, viral, insects, and nematodes play a crucial role leading to overall yield loss of 30–40%, thus threatening its food security. In order to increase the potato production holistic crop protection approach with a range of strategies encouraging natural pest predators, breeding varieties with pest/disease resistance, planting certified seed potatoes, growing tubers in rotation with other crops, and organic composting to improve soil quality are evident. Integrated Nutrient Management (INM) also helps in improvement of quality and quantity of production besides enhancing the sustainability and health of the soil. Proper use of insecticides has proven effective when used as an additional tool in integrated pest management (IPM) practices. Traditional management practices like the use of host-plant resistance, mechanical, biological, chemical, and cultural means of control are not fully expolerd. Conservation farming practices also play important role to

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restore soil and enhancing soil health and play important role to combat climate change issue. The present chapter discusses the importance of improved agronomic practices for sustainable potato production.

Keywords

Solanaceae · Agronomic practice · Pest management · Tuber · PGPR · Sustainable agriculture

8.1 Introduction

Potato, a member of the nightshade family *Solanaceae* and order *Polemoniales*, is an annual herbaceous dicotyledon as far as its vegetative and flowering habits are concerned, but it may be regarded as a perennial as far its capacity for reproduction employing the tubers is considered. Worldwide, potato is the third most important food crop after rice and wheat (FAO 2011). It is grown in 149 countries from latitudes of 65°N to 50°S and from altitudes ranging from sea level to 4000 m (Paul and Ezekiel 2013). It is comprehensively cultivated in China, Russian Federation, Ukraine, Poland, Ireland, Great Britain, Germany, Netherlands, France, Spain, South America, India, and the USA (Mukherjee 2017; Wang et al. 2020). The crop originates from the Peruvian and Bolivian Andes in South America, specifically in Lake Titicaca Basin on the border between Peru-Bolivia. The crop was introduced in India in the mid-seventeenth century probably by Portuguese traders or British missionaries. Potato is one of the principal cash crops of India. The crop covers an area of about 1.86 million ha with an annual production of 41.46 million tons (Mt) with average productivity of 23.12 t/ha in India (2014–2015). West Bengal is the world's highest per day potato productivity state (300 kg/day) and ranks second after U.P in terms of area and productivity (32.96 t/ha). Nutritionally, potato is second to soybean for the amount of protein/ha, with the major storage protein being patatin, one of the most nutritionally balanced plant proteins known and regarded as a wholesome food (Liedl et al. 1987). It contains water (75–80%), carbohydrate (22.6%), starch (14%), sugar (2%), protein (1.6%), fat (0.1%), fiber (0.4%), minerals (0.6%), vitamins (vitamin C rich 17 mg), and energy (97 kcal) (Mukherjee 2017). Besides, it is also a good source of vitamin B (B_1, B_3, and B_6) and minerals such as potassium, phosphorus, and magnesium, and contains folate, pantothenic acid, and riboflavin. It is also a source of essential amino acids like lysine, leucine, tryptophan, and isoleucine. Moreover, potato is low in fat. The crop is also a moderate source of iron, and its high vitamin C content fosters iron absorption. It also contains antioxidants, which also play a critical role in preventing diseases related to aging, and dietary fiber ultimately benefits health.

In the emerging global economic order, the development of agricultural crops is witnessing a rapid transition to the production of agricultural commodities, with potatoes appearing to be a significant crop, ready to sustain and diversify food production in the new millennium. Temperature and unpredictable drought are the two most important abiotic factors, thus affecting world food securities. In developed countries, especially in Europe and the Commonwealth of Independent States, productivity of potato has decreased by 1% per annum over the last 20 years. However, output in developing countries has expanded at an average rate of 5% per year (Falloon and Betts 2010; Wadas and Dziugieł 2020). Asian countries, especially China and India, stoke up this growth. In the recent past, the developing countries share 52% of global potato output stood surpassing that of the developed world. This is a great achievement, considering the share of potato in global production was little more than 20% twenty years ago in the developing countries (Collier et al. 2008). Globally, production and consumption of potato is steadily increasing than the global population. Fresh potato consumption, once the pillar of world potato utilization, is declining in many countries, especially in developed regions. This is mainly because of the harsh weather condition which alarms the selling price. Thus, it becomes a critical threat to future food security (Rana et al. 2020; Mukherjee 2002).

Increasing the production of potato in adverse conditions would require innovative technology to supplement conventional methods that are unable to prevent yield losses. Various agronomic practices not only improve the soil quality but also enhance the yield of potato. Application of N in two split doses, i.e. half at the time of planting and rest at the time of earthing up to produce higher yields and higher N recovery (Du et al. 2020). Equitable use of major and micronutrients plays an important role in improving the quality of produce besides good yield. Integrated nutrient management must for a crop like a potato. Moreover, the proper use of insecticides has proven effective when used as an additional tool in integrated pest management (IPM) practices. The use of bio-resources such as plant growth-promoting rhizobacteria (PGPR) and other conservation farming practices also play an important role to restore soil and enhancing soil health and play an important role to combat climate change issues.

This chapter focuses on the major factors affecting potato production, various components for its management like integrated nutrient management (INM), integrated pest management (IPM), conservation farming, and cultural practices to improve soil quality that helps to restore degraded soils which leads to enhance its production and yield. It also describes various management practices for sustainable production.

8.2 Factors Constraining Potato Production

Many factors affect the productivity of potato. As potato (edible and reproductive part) is the semi-perishable tuber, there are more chances for disease to accumulate in each planting season which ultimately affects its yielding potential. Other constraints such as traditional potato production system, scarce germplasm resources for cultivar development, shortage of high-quality seed potatoes, limited knowledge on postharvest handling of the product, and poor technology transfer systems also hinder its productivity (Adane et al. 2010). Moreover, storage and transportation technologies are also affecting potato production, as they are the major constraints for the healthy development of the potato industry. Several factors are affecting the growth and production of potato which are listed in Table 8.1.

8.3 Agronomic Management Practices

An agronomic practice alludes to the scientific investigation of soil management and crop production. It includes the water system and the use of herbicides, pesticides, and compost. Agronomy stresses staple sustenance crops, for instance, corn, rice, potato, beans, and wheat, which are made on a far-reaching scale and address the foundation of our human sustenance supply. Various agronomic practices that help in the sustainable production of potato presented in Fig. 8.1.

8.3.1 Integrated Nutrient Management (INM)

Integrated nutrient management is agronomic practice for the adjustment and maintenance of soil fertility and provides nutrients to the plant at an optimum level for sustaining crop productivity through optimization of all possible resources of plant nutrients in an integrated manner. This practice of nutrient management achieved greater significance in the last few years because of two reasons. First, fertilizer production in India at the present level is not enough to meet the entire plant nutrient requirement to meet productivity. Secondly, long-term experiments (LTEs) conducted in India or elsewhere reveal that neither the organic sources nor the fertilizers in isolation can achieve sustained production under intensive cropping (Serderov et al. 2020). The major components of INM are fertilizers, organic manures, legumes, crop residues, and bio-fertilizers which are explained below.

8.3.1.1 Chemical Fertilizers

Fertilizers contribute to be the most important component of INM. To supply large amounts of nutrients in intensive cropping with high productivity there is increased independence on fertilizers. Moreover, their consumption is not only inadequate but also imbalanced. The $N:P_2O_5: K_2O$ use ratio is quite wide, whereas application of micronutrients and K, S is usually ignored. The domestic production of fertilizer is not sufficient to meet the requirements. On the other hand, problems like global price hike of fertilizers and raw materials would not permit fertilizer import in large quantities leading to a big gap between fertilizer supply and consumption. While organics and bio-fertilizers are expected to bridge a part of this gap, the effective use of fertilizers in narrowing the nutrient supply gap also needs greater emphasis.

Table 8.1 Various factors affecting potato production

Factors	Description
Biological characteristics	The biological characteristics of potato are itself a big constraint. The characteristics like low multiplication rates of seed tubers, costs related issues for maintaining seed quality through successive multiplications, and other technical difficulties, owing to the potato's susceptibility to soil and seed-borne insect pests and diseases
Lack of efficient seed systems	For regular multiplication and distribution of certified seed tubers and the rapid deployment of new and improved varieties many developing countries lack efficient systems. Factors includes lack of managerial expertise, limited technical capacity, and inadequate resource allocations to seed systems
Diseases and insect pests	Diseases and insect pests are another major constraint. New strains of late blight have continued to spread in many developing countries. Late blight constitutes the most serious threat to potato production. Second to late blight is bacterial wilt found particularly in warmer, more tropical regions also pose severe threat to potato production. The impact of insect pests varies between regions and seasons of the year. Major insect pests include aphids, tuber moths, leaf miners, Colorado potato beetle and Andean potato weevil
High production costs and lack of credit	In comparison to other food crops, production of potatoes is capital-intensive. With limited access to credit and few means of mitigating the risks, small-scale farmers find it difficult to compete in potato production. The current global financial crisis could leave a great number of farmers with little money and no credit to invest in production
Price instability	Small-scale potato growers are susceptible to abrupt changes in input and output prices. Year-to-year and seasonal price changes can affect small growers who lack the financial resources and resilience of larger producers and cooperatives
Inefficiency of local markets	Potato prices are usually decisive by supply and demand. It is a crop of low-income farmers and consumers to ride out episodes of food price inflation. However, its profitability totally depends on efficient local markets
Limited access to higher value markets	Rapidly growing processing segment as well as to potato export markets helps the small-scale potato growers to earn profit
Inadequate capacity building initiatives	Programs should be carried out in order to upgrade the skills of potato growers need to be matched by government efforts like monitoring and enforce regulations on pesticide use
Lack of support to farmer organizations and entrepreneurs	Support for local entrepreneurship and potato farmer groups is lacking in many developing countries to improve seed quality and promote variety development. In Argentina, efforts are being made by public and private sector to transfer technology for integrated crop management to its contract growers

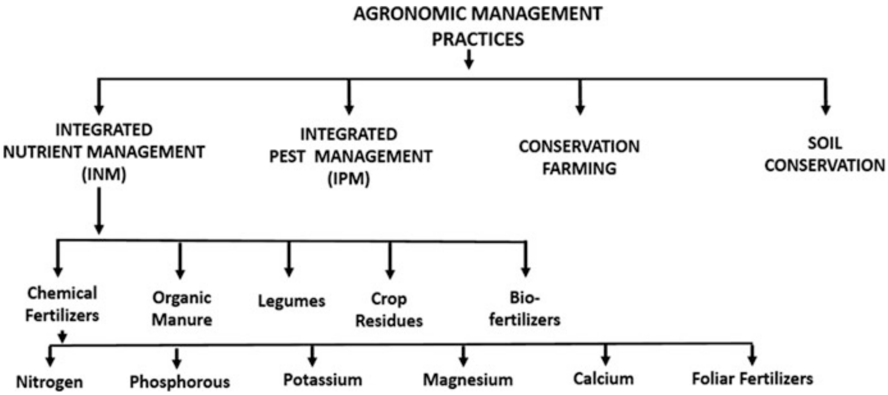

Fig. 8.1 Agronomic management practices for sustainable potato production

Fertilizer utilization by the crops varies from 30 to 50% in the case of N, 15–20% in the case of P, and less than 5% in the case of micronutrients. Thus a significant amount of applied nutrients is lost through various pathways. Increased nutrient use efficiency should be a prioritized area of research for restoration and improvement of soil health and minimizing the cost of crop production.

Nitrogen

The amount of nitrogen applied to a potato crop varies from 100–300 kg/ha depending on the soil characteristics and purpose of the crop. However, excessive or high nitrogen doses stimulate haulm growth, delay tuber formation, and ultimately affect tuber quality (low dry matter content, high reducing sugar content, and high protein and nitrate content). However, a split application might be preferred if there is a risk of leaching (i.e., heavy watering on light soils) or scorching (application of large quantities of fertilizer under dry conditions).

Phosphorus

Phosphorus imparts to the early development of the crop and tuberization. It enhances the crop's dry matter content and ameliorates the tuber's storage quality. Usually, more than 100 kg/ha is applied, while on phosphorus-fixing soils much higher doses are preferred.

Potassium

Potassium not only boosts yields but also improves tuber quality of potato (size, starch content, and storability). An ample supply of potassium can also help to minimize internal blackening and mechanical damage and has been associated with increased stress tolerance.

Magnesium

Attention should be paid to magnesium requirements, especially when potatoes are grown on light acid soils. Inadequate application of potassium and nitrogen in the form of ammonium reduces the uptake of magnesium.

Calcium

Potatoes are tolerant of soil acidity, hydrogen ion concentration of 4.8 leads to crop failure due to calcium deficiency. Liming may be necessary. Seed potatoes need to be grown in soils with sufficient calcium. Seed tubers which are calcium deficient are failed to sprout properly.

Foliar Fertilizers

Plants take nutrients more efficiently through stomata in their leaves as compared to root. Foliar fertilizers contain both macro and micronutrients. They are absorbed by the leaves and have an immediate effect on plant growth. They may help to overcome apparent nutrient deficiencies, especially micronutrients, and support plant recovery following stress events, such as frost and drought.

8.3.1.2 Organic Manures

Organic manures like FYM, urban compost, crop residues, human excreta, rural compost, sewage-sludge, press mud, and other agro-industrial wastes have large nutrient potential. Traditionally FYM and compost have been the most important manures for maintaining soil fertility and ensuring yield stability. Other organic sources of nutrients such as non-edible oilcake and wastes from various industries are also there. Besides, there are several industrial by-products and municipal wastes with fair nutrient potential. However, these nutrient-carriers have not been properly evaluated to establish their fertilizer equivalents. Thus, there is an urgent need to integrate these sources depending on their availability in different crops and cropping systems. The industrial by-products like spent-wash from a distillery, molasses, press mud, etc., from the sugar industry and wastes from other food processing industries have good manorial value. Sulphitation press mud (SPM) has a great potential to supply nutrients and has favorable effects on soil properties. SPM has assumed great importance as a nutrient supplement in sugarcane-ratoon-wheat and other intensive cropping systems of the sugarcane growing areas. Sewage-sludge and municipal solid wastes (MSW) are also important nutrient sources available for integration with fertilizer inputs, but proper cautions have to be taken to avoid any potential threat of pathogens and heavy metal load. These nutrient sources have lost their relative importance over time in crop production as they are bulky in nature with low nutrient content and short in supply. Although, cost and their limited supply made it necessary to search for alternative and renewable sources of plant nutrients leading to major interest in organic recycling. Less than 50% of the manurial potential of cattle dung is utilized at present, a major proportion is lost as fuel and droppings in non-agricultural areas. Cattle dung and other farmyard wastes recycled back to the soil as manure, substantial nutrients are lost due to inadequate methods of manure preparation and its amount of application. Organic manures not only supply macro and micronutrients, but it also help in improving the physical, chemical, and biological properties of the soils.

8.3.1.3 Legumes

Legumes are considered as soil fertility restorers because of their ability to obtain N from the atmosphere in symbiosis with rhizobia. Legumes are a major ingredient of INM when grown especially for fodder or grain in a cropping system, or when introduced for green manuring. Legumes grown as green manure, forage, or grain crops improved the productivity of the rice-wheat cropping system (RWCS) and rejuvenated soil fertility (Yadav et al. 2000).

8.3.1.4 Crop Residues

Crop residues have several competitive uses and are considered as an important component of INM. However, in North-West India mechanical harvesting is still practiced and the leftover residue is used in the field as a part of nutrient supply. Moreover, cereal crop residues are valuable cattle-feed and it can be used to supplement the fertilizers. Disposal of rice straw has been a great concern in Trans and Upper Gangetic Plains. In these areas, farmers prefer to burn all these residues in situ which causes environmental pollution on one hand and loss of potential nutrients on the other hand. Although, residue recycling in the field helps to build stable organic matter in the soil and also helps to sustain the yield. Usually, stubbles varies from 0.5 to 1.5 t/ha in traditional harvesting methods. However, its amount is much higher in practices like mechanical harvesting. Stubbles produced from coarse cereals, i.e. sorghum, maize, pearl millet, etc., are difficult to decompose and are normally collected and burnt during land preparation causing significant loss of plant nutrients.

8.3.1.5 Bio-Fertilizers

Bio-fertilizers are the materials containing living or latent cells of agriculturally beneficial microorganisms that play an important role in improving soil fertility and crop productivity due to their ability to fix atmospheric N, solubilize/mobilize P, and decompose farm waste resulting in the release of plant nutrients (Giri et al. 2019). The benefit from these microorganisms depends on their number and efficiency which, however, is governed by soil and environmental factors. Bacterial cultures, i.e. *Rhizobium, Azospirillum*, and *Azotobacter* have the potential to fix atmospheric N which in turn escalates N supply to the crops. Bacterial cultures of *Pseudomonas* and *Bacillus* and fungal culture of *Aspergillus* help in the conversion of insoluble P into usable forms, hence, improve phosphate availability to the crops. Similarly, Arbuscular Mycorrhizae (AM) fungi increase uptake of P with larger soil volume. *Rhizobium* is the primary symbiotic fixer of N and it is the most well-known bacterial species. These bacteria lead to the formation of lumps or nodules where the N fixation takes place by infecting the roots of leguminous plants. The bacterium's enzyme is a rich source of N to the host plant to furnish nutrients and energy for the activities of the bacterium. The *Rhizobium*-legume association can fix up to 100–300 kg N/ha in one crop season and certain situations leave substantial N for the crop. This symbiotic association could meet 80% of the N requirement of the legume crop. *Azotobacter* free-living N-fixer imparts positive benefits to the crops through a small increase in N input from BNF, development, and branching of roots, production of plant growth hormones, enhancement in the uptake of NO^{-}, NH^{+}, H PO^{-}, K^{+}, and Fe^{+}, improved water status of the plants, increased nitrate-reductase activity, and production of antifungal compounds. In irrigated wheat, a significant response to *Azotobacter* inoculation was recorded in a large number of on-farm trials. *Azotobacter* contribute 20–25 kg N/ha. *Azospirillum* fixes N by colonizes with the root mass. Hence, shows positive interaction with applied N in several field crops with an average response equivalent to 15–20 kg/ha of applied N. Several strains of P solubilizing bacteria and fungi have been isolated, and inoculation with P solubilizing microbial cultures is known to increase the dissolution of sparingly soluble P in the soil. Integrated use of microbial cultures with low-grade rock phosphate might add 30–35 kg P_2O_5/ha. Soil inoculation with *Pseudomonas striata* showed a residual effect in succeeding maize on alluvial soil of Delhi, besides increasing grain yield of wheat.

In recent years, K mobilizing bio-fertilizers (KMB) and Zn solubilizing bio-fertilizers (ZnSB) have been added in order to increase the solubility of K and Zn in soil, respectively. There is an extensive need to assess bacteria which play important role in soil solubility (K and Zn). Also, liquid bio-fertilizers have proved superior over conventional (solid) carrier-based ones. Blue-green algae (BGA) is also another important source of N to wetland rice. As per the estimates, N fixed by BGA inoculation is varied from 20–30 kg N ha^{-1}. Various field studies have also shown that the incorporation of *Azolla* would allow N applications to be reduced by at least 30–40 kg/ha (Dwivedi et al. 2004).

8.3.2 Integrated Pest Management (IPM)

Pest problems may vary from field conditions and seasons because of differences in soil type, cultural practices, cropping history, cultivar, and the nature of surrounding land. Market choice and market conditions also affect the feasibility of management because they determine how a crop must be handled and the value of that crop. Four components are essential to any IPM program: (1) Accurate pest identification, (2) field monitoring, (3) control action guidelines, and (4) effective management methods (Fry 1982).

Almost all pest management tools, including pesticides, are effective only against certain pest species, one must know which pests are present and which are likely to appear. By monitoring, one can get information to make management decisions. Monitoring includes keeping records of weather, crop development, and management practices as well as incidence and levels of pest infestations. Control action guidelines indicate when management actions including pesticide applications are needed to abstain losses due to pests or other stresses.

8.3.3 Conservation Farming

Conservation farming aims at enhancing natural biological processes both above and below ground. The major role of conservation farming is (1) Minimization of mechanical soil disturbances, (2) permanent organic soil cover, (3) diversified crop rotations. By minimizing soil disturbance, it creates a vertical macro-pore structure in the soil, which facilitates the infiltration of excess rainwater into the subsoil and thus improves the aeration of deeper soil layers and further facilitates root penetration.

8.3.4 Soil Conservation

Soil erosion is a major constraint that continues to threaten the sustainability of both subsistence and commercial agriculture. Cultivation of potato requires intensive soil tillage practices throughout the cropping period, which ultimately leads to soil erosion, degradation, and leaching of nitrates. The use of mulch at planting and the “notill” land preparation method is recommended to reduce soil degradation, erosion, and nitrate pollution, and to restore degraded soils aided good potato yields with less requirement of fertilizer. The mulch helps to protect the soil from erosion in the first weeks of the crop. Although mulching reduces the risks of soil erosion and nitrate leaching, it may have some adverse effects (e.g., excessive moisture and reduced soil temperature leading to retarded plant emergence). Hence, it should not be a blanket recommendation. The no-tillage potato is grounded into the soil surface and then covered with a thick layer of mulch, preferably straw, which is fairly stable and does not rot quickly.

8.4 Cultural Practices

Potato tuber develops entirely underground, its quality, shape, disease, and yield are usually influenced by factors like moisture content and humus, texture, and temperature of the soil in which it grows. All these factors render soils for potato production. Therefore, to cope with the adverse effects which affect potato production, it is not only desirable but imperative that proper cultural practices involving strict cognizance of the best methods should be adopted for improving soil conditions. The various cultural practices which enhance potato production are depicted in Fig. 8.2.

Fig. 8.2 Cultural practices for sustainable potato production

8.5 Management Methods

8.5.1 Seed Quality and Certification

Pests can be transmitted in infected seed tubers, including blackleg, bacterial ring rot, late blight, common scab, potato viruses, *Rhizoctonia,* powdery scab, root-knot nematodes, silver scurf, and wilt diseases. To prevent these problems, one must start with healthy stock (Agios 1997). Techniques like micro-propagation and stem cutting have been developed to obtain pest-free potato plants for propagation and production of certified seed tubers. Disease-free stem cuttings or tiny pieces of meristem tissue are cultured and propagated under sterile conditions to produce large numbers of disease-free plantlets or mini tubers (Anonymous 2008).

8.5.2 Biological Control

Any activity of a parasite, predator, or pathogen that keeps a pest population lower than it would be considered as biological control. One of the first assessments that should be made in an IPM program is the potential role of natural enemies and hyper-parasites in controlling pests. Control by natural enemies and hyper-parasites is inexpensive, effective, self-perpetuating, and not disruptive of natural balances in the crop ecosystem.

Bacteria combative to *Erwinia carotovora* are being developed as seed piece treatments for abbreviating seed piece decay and blackleg. Among rhizobacterial *Agrobacterium radiobacter*, *Bacillus subtilus,* and *Pseudomonas* spp. are antagonistic to potato cyst nematodes (*Globodera pallida* and *G. rostochiensis*) though *Pasteuria penetrans* attach PCN (Kerry et al. 2003). Larkin (2007) reported that soil-application of aerated compost tea (ACT) and the combination of ACT with a mixture of beneficial microorganisms reduced stem canker, black scurf and common scab on tubers by 18–33% and 20–23% yield increase in barley/ryegrass rotation, but not in the other rotations. Table 8.2 depicts the effect of organic sources and chemical fertilizers on growth parameters of potato.

Table 8.2 Effect of organic sources and chemical fertilizers on growth parameters of potato

Organic source	Chemical fertilizer	Growth attribute	Reference
FYM	P and K	Potato haulms	Sharma (1986)
Vermicompost	50 per cent RDF	Number of leaves per plant in potato	Patil (1995)
FYM	Inorganic source of nutrients in the ratio of 1:3	Plant height, number of leaves per plant, and leaf area per plant	Sood (2007)
Poultry manure	Reduced RDF	Yield parameters and yield of potato	Md Islam et al. (2013)
FYM	NPK	Yield of potato	Boke (2014)
Cattle manure	NP	Growth rate, and leaf area, average tuber weight, and marketable and total tuber yield	Masrie et al. (2015)
Cattle manure	Mineral NP	Higher tuber yield	Isreal et al. (2018)

8.5.3 Resistant Cultivars

Plant breeding is one of the most important tools available for both the production of the best crop and the management of pests. Pest management is one of the important factors that must be taken into account while choosing cultivars. Cultivars resistant or tolerant of the disease can help reduce losses caused by some soil-borne pathogens and provide long-term, economical protection from conditions that otherwise could inflict severe losses every season (Table 8.3).

Part of every breeding program is the search for resistance to serious diseases, disorders, and nematode pests. Resistance to insect pests is being investigated. New potato breeding selections are assessed for resistance to several viruses, leaf-roll net necrosis, root-knot nematodes, *Verticillium* wilt, scab, blackleg, early blight, and several physiological disorders (Hooker 1983).

8.5.4 Chemical Control with Pesticides

Adequate use of pesticides can not only provide economical protection from pests but also reduce significant losses. In many situations, they are the only feasible means of control. Excessive use of pesticides results in crop damage and hazards to health and the environment. In an IPM, pesticides are used only when field monitoring indicates they are needed to prevent losses (Table 8.4).

Fungicides reduce damage caused by certain foliar pathogens, i.e. late blight, powdery mildew, and severe early blight. Fungicides usually applied before infection occurs or when the disease just begins to develop. Soil fumigants might be used to control nematodes or *Verticillium*.

8.6 Conclusion

The widely-cultivated potato, *S. tuberosum* L., is one of the world's principal food crops. Over the next four decades, the global agriculture industry faces major challenges, as projections suggest that the global population will be between 8.0 and 10.4 billion people, with a median estimate of 9.1 billion. Recently, released studies estimate that worldwide agricultural production will need to grow by 70% over an approximated 45-year interval (between 2005–2007 and 2050), and by 100% in developing countries. The major challenges in sustainable potato production are varying economies of scale, are heterogeneity in soil resources, nutrient availability, pest resistance, weather constraints, demographic changes, and shifts in the availability of arable lands. High-resolution geospatial studies can help in the identification of trends and patterns in local to regional scale commercial production environment, which can in turn encourage the broader adoption of adaptive management strategies that not only increase yield but also promote sustainable land use. Global environmental change (GEC) will lead to elevated temperature in many years, which will in turn involve manipulation of agronomic practices in order to

Table 8.3 Biological control of bacterial and fungal disease of potato

Biocontrol agent	Effective against	Disease	Reference
Antagonistic isolate BC8	*Pseudomonas solanacearum*	Bacterial wilt	Ciampi et al. (1989)
Bacillus subtilis BS 107	*Erwinia carotovora* subsp. *Atroseptica* and *Erwinia carotovora subsp. carotovora*	Blackleg and soft rot	Sharga and Lyon (1998)
Bacillus, *Pseudomonas*, *Rahnella*, and *Serratia*	*Phytophthora infestans* (strain US-8)	Late blight	Daayf et al. (2003)
Bacillus sp. sunhua	*Streptomyces scabiei*	Scab	Han et al. (2005)
Biocine S2HA	*Ralstonia solanacearum*	Brown rot	Kabeil et al. (2008)
Basidiomycetes	*R. solanacearum*	Brown rot	El-Fallal and Moussa (2008)
Burkholderia cepacia	*Fusarium sambucinum*, *F. oxysporum* and *F. culmorum*	Potato dry rot	Recep et al. (2009)
Pseudomonas spp. StT2 and StS3	*Rhizoctonia solani*	Potato black scurf	Tariq et al. (2010)
Pseudomonas koreensis	*Phytophthora infestans*	Late blight	Hultberg et al. (2010)
Lactic acid bacteria	*Phytophthora infestans*	Late blight	Axel et al. (2012)
Pseudomonas fluoresces (Pf2), *Bacillus subtilis* (Bs3) and *Rahnella aquatilis*(Ra39)	*Pectobacterium atrosepticum*	Blackleg	Hoda et al. (2016)
Pseudomonas and *Bacillus* genera	*Dickeya* sp. and *Pectobacterium* sp.	Blackleg	Raoul et al. (2016)
Rhizobacteria	*Globoderaro rostochiensis*	Golden nematode	Salinas et al. (2016)
Brevibacillus formosus strain DSM 9885, and *Brevibacillus brevis* strain NBRC 15304	*Alternaria alternata*	Brown leaf spot	Ahmed (2017)
Bacillus amyloliquefaciens Ba01	*Streptomyces* species	Potato common scab	Lin et al. (2018)

Table 8.4 Detailed description of potato diseases (bacterial, fungal, and viral) and their management

Disease	Causative agent	Symptoms	Management
Bacterial disease			
Blackleg	*Pectobacterium* spp.	Soft rot of seed pieces Black to brown discoloration of the stem, stunting and wilting of affected stems	Cleaning seed handling, planting, and cutting equipment is important
Aerial stem rot/aerial blackleg/aerial soft rot or bacterial stem rot	*Pectobacterium carotovorum* subsp. *carotovorum* (syn. *Erwinia carotovora* subsp. *carotovora*) *Pectobacterium atrosepticum* and *Dickeyadianthicola* (syn. *Erwinia chrysanthemi*)	Water-soaked lesion on the stem, shrivelled stems	Use whole tubers, or allow cut seed pieces to suberize, or cork over, before planting Avoid over irrigation and fertilization
Soft rot	*Pectobacterium carotovorum (*subsp. *carotovorum, odoriferum)* *Pectobacterium atrosepticum, Dickeyadianthicola* *Pseudomonas, Bacillus and Clostridium*	Tuber becomes infected, foul smelling odor, non-emergence of plants, wilting, browning of tissues, haulm desiccation and plant death	Avoid harvest when temperatures are >65–75 °F, particularly when conditions are wet Provide protection for harvested tubers from sunscald, heating or desiccation Avoid bruising during harvest and handling Maintenance of soil calcium level
Ring rot	*Clavibacter michiganensis* subsp. *sepedonicus*	Shortened internodes, slight discoloration	All tissue cultures should be tested by PCR before propagation
Brown rot	*Ralstonia solanacearum*	Prominent milky ooze when an infected lower stem is placed in water	Plant disease-free seed in non-infested soil and crop rotation
Common scab	*Streptomyces scabies*, *S. acidiscabies* and *S. turgidiscabies*	Initial infections result in superficial reddish-brown spots on the surface of tubers	Maintain high soil water levels Avoid planting scabby seed tubers Scab-resistant varieties are useful Maintain soil pH levels at 5–5.2
Fungal disease			
Alternaria Brown rot	*Alternaria alternata*	Small, dark round necrotic lesions, leaves	Cultural practices and foliar fungicides

(continued)

Table 8.4 (continued)

Disease	Causative agent	Symptoms	Management
		may be affected, drying up	Provide adequate fertilization Fungicides are very efficient for controlling brown leaf spot
Early blight	*Alternaria solani*	Small, black lesions. Spots enlarge, and by the time they are one-fourth inch in diameter or larger, concentric rings in a bull's eye pattern can be seen in the center of the diseased area	Crop rotation and destruction of plant debris and weed hosts are used to reduce the sources of inoculum Rotation, avoid over irrigation Fungicide programs are the most effective means to control the disease
Late blight	*Phytophthora infestans* (Mont.)	This disease damages leaves, stems, and tubers. Affected leaves appear blistered as if scalded by hot water and eventually rot and dry out Affected stems begin to blacken from their tips, and eventually dry out Affected tubers display dry brown-colored spots on their skins and flesh	Good field drainage and proper plant spacing for optimal air Proper sanitation is necessary At planting, seed treatment fungicides exist Deep hilling can be used to protect tubers from sporangia washing off leaves Avoid excessive fertilization to prevent canopy overgrowth Fungicide application is considered an integral part of late blight management
Powdery mildew	*Erysiphe cichoracearum*	Disease begins with brown flecks on the leaves. These flecks can coalesce into larger, water-soaked regions that may appear black Powdery mildew forms distinctive white, powdery patches on leaves and stems Leaves, beginning at the base, yellow then become necrotic. Left unchecked, the plant may die	Elemental sulfur applied as a dust or spray is sufficient to control the disease if treated before the pathogen is widespread If the disease is widespread, there are multiple fungicides labeled for use

(continued)

Table 8.4 (continued)

Disease	Causative agent	Symptoms	Management
Viral disease			
Mild mosaic	Potato virus A	Chlorotic mottling, slight crinkling	Kill vines in seed plots early
Yellow dwarf	Potato yellow dwarf virus	Plants often produce small, misshapen tubers, cracks are common	Plant disease-free seed potatoes, rogue diseased plants control insect vectors
Stem-end browning	Unknown; virus suspected	Stem-end browning	Plant resistant varieties
Witches' broom	Virus suspected; possibly a mycoplasma	Produce many marble-sized tubers	Plant disease-free seed and practice careful roguing

improve crop efficiency. Worldwide, various researchers believed locally-to-regionally specified sustainable and environmentally responsible potato production systems will help meet the challenges for long-term and country-driven food security and poverty alleviation.

References

Adane H, Meuwissen MPM, Agajie T, Lommen WJM, Lansink AO, Admasu T, Struik PC (2010) Analysis of seed potato systems in Ethiopia. Amer J Potato 87:537–552

Agios GN (1997) Plant pathology, 4th edn. Academic Press, Cambridge, p 229

Ahmed AIS (2017) Biological control of potato Brown leaf spot disease caused by *Alternaria alternata* using *Brevibacillus* formosus strain DSM 9885 and *Brevibacillus brevis* strain NBRC 15304. J Plant Pathol Microbiol 8:1–8

Anonymous (2008) UC IPM pest management guidelines: potato UC. ANR Publication, New York

Axel C, Zannini E, Coffey A, Guo J, Deborah MW, Elke KA (2012) Eco-friendly control of potato late blight causative agent and the potential role of lactic acid bacteria: a review. Appl Microbiol Biotechnol 96:37–48

Boke S (2014) Effect of organic and inorganic fertilizer application and seedbed preparation on potato yield and soil properties on alisols of Chencha. Int J Nat Sci Res 2:123–132

Ciampi PL, Fernandez C, Bustamante P, Andrade N, Ojeda S, Contreras A (1989) Biological control of bacterial wilt of potatoes caused by *Pseudomonas solanacearum*. Am J Potato Res 66:315–332

Collier R, Fellows J, Adams S, Semenov M, Thomas B (2008) The vulnerability of horticultural crop production to extreme weather events. Effects of climate change on plants: implications for agriculture. Aspects Appl Biol 88:3–14

Daayf F, Adam L, Fernando WGD (2003) Comparative screening of bacteria for biological control of potato late blight (strain US-8), using in-vitro, detached-leaves, and whole-plant testing systems. Can J Plant Pathol 25:276–284

Du X, Zhang X, Kong L, Xi M (2020) Split application under reduced nitrogen rate favors high yield by altering endogenous hormones and C/N ratio in sweet potato. Agronomy 10:1243

Dwivedi BS, Singh VK, Dwivedi V (2004) Application of phosphate rock with or without *Aspergillus awamori* inoculation, to meet phosphorous demand of rice-wheat system in the indo-Gangetic plains of India. Aust J Exp Agric 44:1041–1050

El-Fallal A, Moussa Z (2008) Prospects for Biocontrol of Brown rot disease of potato *in vitro* and under greenhouse conditions. Plant Pathol J 7:54–64

Falloon P, Betts R (2010) Climate impacts on European agriculture and water management in the context of adaptation and mitigation: the importance of an integrated approach. Sci Total Environ 408:5667–5687

FAO (Food and Agriculture Organization) (2011) Food and agricultural commodities production. Food and Agriculture Organization of the United Nations, Rome

Fry WE (1982) Principles of disease management. Academic Press, Cambridge, p 378

Giri B, Prasad R, Wu Q-S, Varma A (2019) Biofertilizers for sustainable agriculture and environment. Springer International Publishing. ISBN 978–3–030-18932-7. https://www.springer.com/gp/book/9783030189327

Han JS, Cheng JH, Yoon TM, Song J, Rajkarnikar A, Kim WG, Yoo ID, Yang YY, Suh JW (2005) Biological control agent of common scab disease by antagonistic strain *Bacillus sp.* sunhua. J Appl Microbiol 99:213–221

Hoda H, El-Hendawy, Kamal Abo-Elyousr AM (2016) Combination of different antagonistic bacteria to control potato blackleg disease caused by *Pectobacterium atrosepticum* under greenhouse and field conditions. Int J Phytopathol 5:35–43

Hooker WJ (1983) Compendium of potato diseases. The American Phytopathological Society, St. Paul

Hultberg M, Bengtsson T, Liljeroth E (2010) Late blight on potato is suppressed by the bio-surfactant producing strain *Pseudomonas koreensis* 2.74 and its bio-surfactant. Bio Contr 55:543–550

Isreal Z, Tana T, Wogi L, Mohammed A (2018) Effect of combined use of cattle manure and inorganic nitrogen and phosphorus on yield components yield and economics of potato (*Solanum tuberosum* L.) in Belg and Meher season at Abelo area Masha District, South-Western Ethiopia. J Agric Sci Food Res 9:1–10

Kabeil SS, Amer MA, Matarand SM, El-Masry MH (2008) In planta biological control of potato Brown rot disease in Egypt. World J Agri Sci 4:803–810

Kerry B, Barker A, Evans K (2003) Investigation of potato cyst nematode control. Nematode interaction unit, plant-pathogen interaction division, Rothamsted Research, Harpenden Herts, AL5 2JQ no. HH3111TPO, 87. http://programs.cphst.org/pcn/

Larkin RP (2007) Relative effects of biological amendments and crop rotations on soil microbial communities and soil-borne diseases of potato. Soil Biol Biochem 40:1341–1351

Liedl BE, Kosier T, Sesbarought SL (1987) HPLC isolation and nutritional value of a major potato tuber protein. Amer Potato J 64:545–557

Lin C, Tsai CH, Chen PY, Wu CY, Chang YL, Yang YL, Chen YL (2018) Biological control of potato common scab by *Bacillus amyloliquefaciens* Ba01. PLoS One 13:1–8

Masrie B, Dechassa N, Tana T, Alemayehu Y, Abebie B (2015) The effects of combined application of cattle manure and NP fertilizers on yield and nutrient uptake of potato in north-eastern Ethiopia. Int J Hortic Agri 3:1–23

Md Islam M, Akhter S, Majid NM, Ferdous J, Alam MS (2013) Integrated nutrient management for potato (*Solanum tuberosum*) in grey terrace soil (Aric Albaquipt). Australian J Crop Sci 9:1235–1241

Mukherjee A (2002) Perspectives of the silent majority: air pollution, livelihood and food security. Concept Publishing Company, New York

Mukherjee D (2017) Improved agronomic practices and input use efficiency for potato production under changing climate: improved practices for potato production. IGI Global, Hershey, pp 105–132

Patil, MS (1995) Integrated nutrient management of commercial vegetables. M.Sc. Thesis, University of Agricultural Science, Dharwad, Karnataka

Paul V, Ezekiel R (2013) Scientific storage options crucial for potatoes. Agric Today (Year Book), The National Agriculture Magazine, pp 134–137

Rana A, Dua VK, Chauhan S, Sharma J (2020) Climate change and potato productivity in Punjab: impacts and adaptation. Potato Res 63:597–613

Raoul d EY, Cigna J, Quetu LA, Caron A, Munier E, Beury CA, Helias V, Faure D (2016) Biocontrol of the potato blackleg and soft rot diseases caused by *Dickeya dianthicola*. Appl Environ Microbiol 82:268–278

Recep K, Fikrettin S, Erkol D, Cafer E (2009) Biological control of the potato dry rot caused by *Fusarium* species using PGPR strains. Biol Contr 59:1–390

Salinas CA, Nava DC, Luna RM, San Martin RE, Rivera FA, Trigos A (2016) Antagonistic bacteria affecting the Golden cyst potato nematode (*Globodera rostochiensis* Woll.) in the region of Perote, Veracruz, Mexico. Global Adv Res J Microbiol 5:16–22

Serderov VK, Karaev MK, Serderova DV (2020) Promising potato cultivars for industrial processing in Dagestan. Russian Agric Sci 46:337–340

Sharga BM, Lyon GD (1998) *Bacillus subtilis* BS 107 as an antagonist of potato blackleg and soft rot bacteria. Can J Microbiol 44:777–783

Sharma RC (1986) Nitrogen management in the presence of FYM and PK fertilizers on acid soils of Shimla. J Agric Sci Combodia 107:15–19

Sood MC (2007) Integrated nutrient supply and management for potato production in mid hills of Shimla. Potato J 34(1–2):101–102

Tariq M, Yasmin S, Fauzia YH (2010) Biological control of potato black scurf by rhizosphere associated bacteria. Braz J Microbiol 41(2):439–451

Wadas W, Dziugieł T (2020) Quality of new potatoes (*Solanum tuberosum* L.) in response to plant bio-stimulants application. Agriculture 10:265. https://doi.org/10.3390/agriculture10070265

Wang C, Zang H, Liu J, Shi X, Li S, Chen FU, Chu Q (2020) Optimum nitrogen rate to maintain sustainable potato production and improve nitrogen use efficiency at a regional scale in China: a meta-analysis. Agron Sustain Dev 40:37. https://doi.org/10.1007/s13593-020-00640-5

Yadav RL, Singh SR, Pasal K, Dwivedi BS, Batta RK, Singh AK, Patil NG, Chauhari SK (2000) In: Yadav JSP, Singh GB (eds) Natural resource management for agricultural production in India. Secretary General, New Delhi, pp 775–870