29 Integrated Disease Management in Sugar Beet for Sustainable Productivity

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Abstract

Integrated disease management is a strategy for management of plant diseases involving all the essential and beneficial methods which a grower needs for obtaining healthy crop. Adapting this technology, the growers are benefitted by coping up with economical losses they face through the occurrence of disease in sugar beet. Extensive researches in the field of pathology are being done for protecting the crop from various diseases by developing new tools and resistant varieties. Disease surveillance and forecasting in the areas where sugar beet are grown is effective and competent method for managing the diseases for a prolonged period. The first and foremost defense line is the development of resistant varieties against various diseases through either conventional or modernized biotechnological means. Biological, chemical, and cultural are also the part of this management strategy. Novel formulations are also being designed for coping up with the problems associated with sugar beet diseases. The antagonistic nature of many beneficial microbes against pathogen-causing diseases has also gained importance considering the environment-friendly aspect. The amalgamation of these strategies will result in improving the sugar beet yield and production.

Keywords

Integrated · Disease management · Pathogens · Sugar beet

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Abbreviations

CLEs	Crude lipopeptide extracts
IDM	Integrated disease management
IPM	Integrated pest management
PCNB	Pentachloronitrobenzene
SDHI	Succinate dehydrogenase inhibitor

29.1 Introduction

Sugar beet (*Beta vulgaris* L.) cultivation is well known in many tropical countries of the world. It is being used as an alternative producer of sugar. The healthy production of this crop has been affected by the onslaught of different pernicious plant pathogens. The attack of pathogens on healthy sugar beet crops has been a threatening alarm for the growers and is a concerning problem. The cultivation of sugar beet for years in the same area is a favorable condition for severe disease incidence. There are several root rot diseases, caused by *Rhizoctonia*, *Sclerotium*, and *Fusarium* species, which have caused a strong impact on sugar beet productivity due to which growers suffer huge economical losses (Agnihotri 1990). In addition, foliar diseases also do not lack behind in causing an impact on crop productivity. As the climate is changing, the occurrence of new pathogens as well as species depending on the region is also causing more losses in productivity (Misra et al. 2021). It has been illustrated that when root and seed crops are grown in a nearby area, the chances of disease transmission increase from seed to root crop (Agnihotri 1990).

Management of diseases is an important aspect to maintain the losses from not increasing the disease to above the economic threshold point of injury. It is not necessary that a single pathogen attacks a variety at a time and even the type of pathogen may also vary from fungal, bacterial, and mycoplasmal infection to viral infections. While processing sugar beet in factories, it becomes difficult to treat a single variety at a time and is also a matter of large time consumption. This paved the way for integrated disease management of sugar beet as a better option for controlling the diseases. Plant production through an integrated approach is a new economic method for producing high yield and healthy crop production. The term integrated management (IPM) has been used initially for insect-pests, but later this has also now been used for disease management too. Integrated disease management (IDM) is engaged in the application of pesticides on the basis of plant requirements when the disease incidence surpasses the economic threshold levels. This results in endorsing the use of biocontrol agents. IDM is a strategy for moving towards greener alternatives rather than chemicals and engrosses on the limited application of fungicides. Elimination or reduction of the initial inoculums along with the reduction in its efficiency, delay in disease incidence, and enhancing the resistance capability of the host are some of the objectives of this strategy (Gurjar et al. 2018).

29.2 Components of Integrated Disease Management (IDM) and their Application in Sugar Beet

Generally, there are four main components of IDM. These are host resistance, cultural, biological, and chemical controls.

29.2.1 Host Resistance

In this component, suppression of disease pathogen and its development occurs through the use of resistant genotypes. Growers are always interested in such resistant varieties for their cultivation as it will cause lesser investment during crop protection. In such types of genotypes, disease incidence is slow and the damage caused by the pathogen also appears to be less on the plant. In rhizomania of sugar beet, the use of resistant cultivars can reduce infection to some extent. Studies revealed that genetic resistance is a better option for effectively controlling sugar beet root rot disease, particularly from *Rhizoctonia solani* (Sherf and MacNab 1986; McGrath et al. 2015). However, developing resistant variety against any disease may take a long duration approximately 8–10 years. In the 1950s, the development of *Rhizoctonia*-resistant cultivar was first came into existence with the involvement of multiple resistant genes (Panella and Ruppel 1996; Gaskill 1968; Hecker and Ruppel 1975). Resistant/susceptible varieties have been preferred by the sugar beet growers due to their high yield (Haque and Parvin 2021); however, partial resistant varieties may also be grown to minimize the disease incidence rate (Behn et al. 2012; Brantner and Windels 2009). Bolz and Koch (1983) and Hecht (1989) first time reported the partial resistance varieties, viz., Dora and Lena against rhizomania. Rizor is another such resistant cultivar with superior resistance against this disease (Richard-Molard 1985; De Biaggi 1987).

Jacobsen (2006) revealed that the use of resistant varieties against *Fusarium* root rot disease in sugar beet is a good management strategy. In the case of *Cercospora* leaf spot disease, resistance in cultivar depends on many quantitative aspects (Rossi 1995). Studies reported that measurement of r-reducing resistance could be a good option for assessing the resistance level (Lapwood 1971; Parleviet 1976; Johnson and Wilcoxon 1978). Kawe cercopoly and USH 9B are also resistant to *Cercospora* disease (Agnihotri 1990). For a variety to be resistant against this disease, 3 hydroxytyramine content in the foliage was one of the associated parameters (Agnihotri 1990).

Agnihotri (1990) illustrated some highly tolerant varieties against *Sclerotium* root rot. To name a few, C-W 674, Maribo resistapoly, Kawe Cercopoly, and USH-9 B. Moreover, two resistant lines have also been developed, viz., 75 PI and 7326, and at that time the inclusion was the immediate need at commercial basis for growers. Furthermore, Sharpes Klein E is known to have resistant capability for powdery mildew disease, while some USA varieties such as US-9 and US-10 were susceptible to this pathogen, yet they are commercially being grown over a large area (Agnihotri 1990).

29.2.2 Cultural Practices

In this strategy, the favorable environment for the pathogen is disturbed making the environment less feasible for the pathogen to develop. This is done by either disturbing their reproduction cycles or increasing the growth of natural enemies or by many such means. Intercropping, crop rotation, and shifting in sowing dates for disease escape are also involved under this approach.

29.2.2.1 Use of Healthy Seeds

Healthy seeds are the foundation of a healthy plant. Agnihotri (1990) reported several techniques for protecting the seeds prior to planting. For *Alternaria* leaf spot disease, seed disinfection should be done by 0.25 percent thiram or captan for lowering seed-borne infection. In the case of *Cercospora* leaf spot, treatments with aretan 2 g/kg seed, captan 2.5 g/kg seed, or thiram 2.5 g/kg seed were preferred, but for phoma leaf spot soaking of seeds with thiram solution (0.2% concentration) at 30 °C for 24 h has been reported for seed treatment. Jacobsen (2006) revealed another strategy for the areas where this disease is more prone; seed production for such areas should be done in dry conditions under surface irrigation. In case of diseases in stecklings treatment, thiram or thiophanate methyl (0.1%) was effective for storage rot (Agnihotri 1990).

29.2.2.2 Crop Rotation

Crop rotation may be a more practical approach to the reduction of soil inoculums. Cereals and grasses should be taken in rotation for *Rhizoctonia* root rot (Agnihotri 1990). Buhre et al. (2009) and Koch et al. (2018) reported that in this crop, rotation with other crops, particularly nonhost cereal crops like wheat, should be done at least after 3 years; for instance, in *C. beticola* (Agnihotri 1990). Promising results were illustrated in the number of studies on cover crops (*brassica*) as a controller for *Rhizoctonia* infection and many other soil-borne pathogens in sugar beet (Kundu and Nandi 1985). For *Sclerotium* root rot disease, crop rotation with crops that have less susceptibility helps in reducing the disease potential (Jacobsen 2006; Agnihotri 1990). Leach and Davey (1942) revealed that usage of ample amount of nitrogen as fertilizer and other essential nutrients in the soil in areas prone to this disease will offer strong plant growth causing a reduction in damage by the disease. In violet root rot disease, susceptible crops should not be used for crop rotation like beans, potatoes, peas, etc. (Jacobsen 2006) and so is the case for phoma disease (Agnihotri 1990).

29.2.2.3 Other Miscellaneous Cultural Practices

The removal of crop debris and water management in disease helps in lowering the primary inoculums and disease spread. This is evident more in case of soil-borne diseases such as *Rhizoctonia, Fusarium, Sclerotium*, etc. (Gurjar et al. 2018). Even for *Cercospora* leaf spot, the crop debris remain after harvesting should be buried in the soil by deep plowing (Agnihotri 1990). Early planting/sowing also prevents the onslaught occurrence of diseases. This is seen in rhizomania, *Fusarium* root rot, black root rot, *Cercospora*, and *Sclerotium* root rot diseases (Jacobsen 2006; Agnihotri 1990). In the case of *Sclerotium* root rot, planting date of sugar beet has a strong impact on diseases' incidence (Agnihotri 1990). As per an Indian study, planting of this crop in the submountain areas of Uttar Pradesh by tenth November significantly lowers the rotting disease in sugar beet roots (Thakur and Mukhopadhyay 1972). Agnihotri (1990) revealed that disease incidence rate varies for *Cercospora* with the month of planting. Lower incidence rate was seen when crop was sown in October, while highest when it was sown in December under Indian conditions. Early sowing with optimum dose of fertilizer has been recommended for downy mildew. Seed crop must be separated from the root crop at least by 400 m (Agnihotri 1990). Early plowing of the fields is another way by which the inoculums of pathogens could be reduced. In the case of *Fusarium* root rot, the incidence rate can be controlled by 18% (Maui et al. 2020). Field sanitation by burning of infected crop debris and deep ploughing are recommended. Clean roots without wounds, cuts, or cracks should be stored (Agnihotri 1990). The destruction of sclerotia and hyphae of the fungus *Sclerotium* spp. in soil can be effectively done by deep ploughing. Even burning of infected roots and foliage was also known to be effective for reducing the pathogen of *Sclerotium* root rot. Similarly, in case of *Alternaria* leaf spot, foliage should be destroyed by immersing deep under the soil. Likewise, in case of powdery mildew disease, crop residue annihilation is important as cleistothecia survive in plant residues (Agnihotri 1990).

Fusarium root rot as well as weed growth control in particularly Chenopodiaceae is a must (Jacobsen 2006). The best management for *Pythium* and *Phytopthora* root rots was reported to have reduced moisture content in the soil (Jacobsen 2006; Schneider and Whitney 1986). For the management of black root rot disease, soil drainage is important along with weed control, particularly *Chenopodium* and *Amaranthus,* and rotation with other nonhost crops. The application of oat green manures is a better option for managing this disease (Windels and Bratner 2002). Application of ammonium fertilizer 160 kg N per hectare provides adequate *Sclerotium* root rot control (Agnihotri 1990; Thakur and Mukhopadyay 1972). Soil indexing also plays an important role as it helps in knowing the requirement of resistant varieties for that area where sugar beet is meant to be grown (Windels and Nabben-Schindler 1996). Soil fumigation has also been reported to be efficient in controlling vector of rhizomania (Jacobsen 2006).

29.2.3 Chemical Control

In this method, the application of pesticides on the basis of plant requirements is involved. This approach is adopted in areas where the disease incidence is rapid and severe during the initial stages of crop growth. In the fungicides group, there are two main types of fungicides. These are protectants and eradicates. Protectants are defined as the ones that stick on the surface of the plants and the mode of action is dependent on pathogen contact. It is important that the spraying of chemicals onto the plant should be uniform. On the other hand, eradicates are the ones that are absorbed by the plants and belong to systemic pesticides, implying that only specific fungi can be controlled by their application. In the case of *Erysiphe betae,* application of Bellis 38% WG, Collis 30% SC, and Tilt 25% EC on sugar beet plants had reduced disease incidence with high root weight and total soluble solids (Aly et al. 2020). Zadehdabagh et al. (2020) reported that a combination of azoxystrobin + difenoconazole fungicide (1 l/ha) causes a reduction in *Cercospora* leaf spot disease and better root yield than carbendazim, thus, stating as a better alternative option against carbendazim fungicide. Duter (0.75 kg per hectare) or dithane Z-78 (2.5 kg per hectare) was another effective fungicide in managing this disease provided the prophylactic spray is given before the usual time of appearance of disease. Among systemic, fungicide Bavistin (300 g per hectare) has been found to be very effective. Two to three sprays are required for adequate control of the *Cercospora* leaf spot disease (Agnihotri 1990).

El-Shabrawy and Rabboh Abd (2020) showed that certain chemicals like copper sulfate, zinc sulfate, salicylic acid, ascorbic acid, and potassium silicate had higher effectiveness in controlling powdery mildew disease incidence with high root weight and sucrose content. Agnihotri (1990) reported that application of sulphur (15–20 kg per hectare), wettable sulphur (1.2 kg per hectare), benomyl (0.5 kg per hectare), and brestan (800 g per hectare) were effective in giving promising results towards powdery mildew disease management. Application of rovral, tachigaren seed, and fundazol on sugar beet seeds causes a decrease in root rot infection by 8.1–16.6% with high root yield (an increase of 31.5–50.2 c/ha) (Maui et al. 2020). Jacobsen (2006) demonstrated that thiram, prochloraz hot water, and benzimidazole had a significant reduction in *Phoma* leaf spot disease when sugar beet seeds are priory treated with them; however, *Phythium*, hymexazole, and metalaxyl were effective as seed treatment, while metalaxyl could also be used as a soil treatment. Spraying of dithane Z-78 (2.5 kg per hectare) or brestanol (0.7 kg per hectare) showed significant results when the timely application was given thrice for the control of *Alternaria* leaf spot. It is important that the first spray should coincide with the first secondary infection (Agnihotri 1990).

Quinone outside inhibitors (QoI) fungicides (azoxystrobin and pyraclostrobin) are preferred during sugar beet growth as they help in blocking the electron transfer between cytochrome b and cytochrome c1, resulting in uncertain production of ATP (Markell and Khan 2012–2013). These fungicides were effective in controlling *Rhizoctonia* root rot disease (Balba 2007; Haque and Parvin 2021). Liu and Khan (2016) had reported that penthiopyrad application on sugar beet helps in controlling *R. solani* infection. Penthiopyrad can be used either at planting with a dosage of 210, 280, 420, or 550 g a.i./ha or by soil drenching after 1 month of sowing. Penthiopyrad acts as a good mitigator for developing resistant isolates of *R. solani* (Liu and Khan 2016). Succinate dehydrogenase inhibitor (SDHI) fungicides (sedaxane (0.1 μg/mL), penthiopyrad (0.15 μg/mL), and fluxapyroxad (0.16 μg/mL)) were also effective in controlling *R. solani* infection (Sharma et al. 2021). Carboxin, chloroneb, and certain other fungicides had been found to be used for managing *Sclerotium* root rot disease (Jacobsen 2006). Treatment of hymexaole on seeds proved to be successful in managing the disease (Windels and Branter 2004).

Campbell and Klotz (2005) revealed that a combination of hymexazole and biological control strategy gave promising results against *Aphanomyces* root rot disease. Seed treatment with neonicotinoid in the early time of growth helps in controlling the disease incidence in the crop (Strausbaugh et al. 2010). Application of flutriafol-based fungicide helps in controlling *Cercospora beticola*, *Erysiphe betae,* and *Uromyces betae* by acting as an eradicant and longer persistence (Brown et al. 1986). Poncha beta (insecticide) has also been known to manage the curly top disease with seed treatment under idaho conditions (Strausbaugh and Gillen 2006). A combination of Monocut with pomegranate and black pepper extract was revealed to be effective against sugar beet root rot. Pomegranate methanolic extract showed 93.30% inhibition rate, while similar results were also observed with black pepper methanolic extract against *S. rolfsii* (Osman et al. 2021).

Several fumigants like D-D, Vapam, Chloropicrin, methyl bromide, etc. have been found to reduce the inoculums of *S. rolfsii* appreciably. Fungicide like pentachloronitrobenzene (PCNB) and demosan when applied at the rate of 15–20 kg per hectare provide very effective control of the disease. These fungicides should be applied 10–15 days before the usual appearance of the disease in the field. Application of insecticides like Carbafuran (2 kg a.i. per hectare) also drastically reduces the root rot incidence of sugar beet (Mukhopadhyay and Thakur 1977). Of the various chemicals, only PCNB is widely used in sugar beet growing areas. It is cheap and readily available in India. It gives the cost: benefit ratio of 1:4. PCNB is broken down in soil into two compounds, namely, pentachloroaniline and methyl-thiopentachlorphenyl. Pentachloroaniline is highly fungicidal to *S. rolfsii*. It has been found that light irrigation after PCNB application further enhances the efficacy of the fungicide (Agnihotri 1990). Soil around sugar beet roots should be drenched with brassicol (20 kg/ha) for *R. solani* and *R. bataticola* infection. Although this treatment reduces soil inoculums, it is not cost-effective (Agnihotri 1990).

29.2.4 Biological Control

In this approach, a decrease in pathogen occurrence is known by the application of other living organisms. It is one of the most effective and natural means of coping up with harmful pathogens by the use of beneficial microorganisms. Hyper parasites' application is also one better example of it.

29.2.4.1 Trichoderma Spp. as Biocontrol Agent

Trichoderma harzianum, *T. viridie*, and *T. flavus* are some of the species that are being used for sugar beet disease management. *T. viridie*, *T. harzianum*, *and Gliocladium virens* have been demonstrated against *Rhizectonia solani* in vitro (Agnihotri 1990). Moussa (2002) observed that *T. harzianum* effectively manages the *R. solani* infection in sugar beet roots. On observing through electron microscopy, *T. harzianum* was found attaching to the *R. solani* by the hyphal coils. Furthermore, *Trichoderma spp.* formulations (Talc-*T. harzianum* followed by Peat-*T. flavus*, Talc-*T. flavus*) and *Talaromyces* were also found to be potential biocontrolling agents in case of *R. solani*-induced damping-off disease in this crop (Kakvan et al. 2013). The efficiency of *Trichoderma* spp., particularly *T. harzianum*, as biological agent against damping-off and root rot disease in sugar beet resulted in improvement of root weight (Abada 1994). Sawan and Mukhopadhyay (1991) showed that when *T. harzianum* inoculum (17.5 g/m ridge) is used as a soil amendment or when treated with metalaxyl (0.1%), the *Pythium* damping-off in sugar beet was controlled effectively. El-Katatny et al. (2020) demonstrated that combination of mint oil treatment and culture filtrate of *T. harzianum* was effective in reducing the germination of fungal spores causing root rot in sugar beet.

T. harzianum and *T. viridie* are commercially used for management of *Sclerotium* root rot. The application of these fungi was given through irrigation water or as broadcast dosage of 140 kg *Trichoderma* granules per hectare (Mukhopadhyay and Upadhyay 1983; Agnihotri 1990). Upadhyay and Mukhopadhyay (1986) revealed that a combination of pentacholoronitrobenzene (low concentration) with *T. harzianum* causes significant control in *Scleortium* root rot disease by decreasing the incidence rate to 76%. Effective management was also seen when mustard oil cake (25 q per hectare) was applied for *Sclerotium* root rot. The benefit of using this organic amendment was observed in soil improvement where sugar beet was grown as beneficial microbes, like actinomycetes, bacteria, fungi population gets enhanced (Mathur and Sarbhoy 1973). These microbes are known to have antagonistic nature for *S. rolfsii*. Alternate drying and wetting of the field is important for the destruction of *S. rolfsii* (Agnihotri 1990).

29.2.4.2 *Bacillus* Spp. as Biocontrol Agent

Bacillus spp. is being applied as a control measure to many foliar diseases and postharvest diseases in sugar beet. *Cercospora beticola* infection in sugar beet has been known to be controlled with the application of Bac B which provides resistance to the crop against this disease (Collins and Jacobsen 2003). Another bacterial isolate, Bac J from *Bacillus mycoides,* had reported having decrease in the incidence rate of *Cercospora* leaf spot by 38–91% (Bargabus et al. 2002). Further, crude lipopeptide extracts (CLEs) of *Bacillus amyloliquefaciens* strains (SS-12.6) had reduced foliar disease incidence rate (Nikolic et al. 2019). Bargabus et al. (2004) showed that two strains of *B. pumilus,* viz., 203-6 and 2037, caused the decline in *Cercospora* leaf spot symptoms by 70%. Kodiak, prepared from *Bacillus subtilis,* has also shown effective results in decreasing the *R. solani* AG 2-2 IIIB infection (Kiewnick et al. 2001). The production of bacteriocin from *B. subtilis* plays an important role in antagonistic mechanisms against pathogens, resulting in pore formation, cell disintegration, and other processes (Caulier et al. 2019). MSU-127, bacillus strain, with Azoxystrobin (low concentration) was helpful in improving the sugar beet yield by 16%; however, when the fungicide was sprayed after 1 month of sowing, root yield was enhanced by 17% as a result of suppression of diseases (Kiewnick et al. 2001).

Rhizobacteria were even efficient in controlling the density of *R. solani in this crop* (Homma 1996). *Application* of *Pseudomonas putida* 40 RNF on pelleted seeds had reduced the incidence of *Pythium* damping-off disease in sugar beet

(Shah-Smith and Burns 1996). Errakhhi et al. (2007) reported that *S. rolfsii* damping-off disease had significantly reduced incidence rate when J-2 isolate of *Streptomyces* was used. Furthermore, two other isolates of the same bacteria (S2 and C) had shown reduction in *Rhizoctonia solani* infection by the formation of siderophore and chitinase (Sadeghi et al. 2006).

29.2.4.3 Other Miscellaneous Fungi as Biocontrol Agent

Mycofumigation is another approach by which sugar beet diseases can be managed. *Muscodor albusitalic* and *M. roseus* application on sugar beet had reduced disease rigorousness against *R. solani*, *Pythium ultimum*, and *Aphanomyces cochliodies*. Furthermore, *Fusarium* wilt disease of this crop was even manageable by mycofumigation (Stinson et al. 2003). Shawki et al. (2020) reported that treatment of seeds with nicotinic acid (5 mM) acts as a protective agent against *F. moniliforme* pathogen. El-Tarabily (2004) illustrated that isolates of *Candida valida, Rhodotorula glutinis,* and *Trichosporon asahii* act as protectants for seedling and mature plants against *R. solani* diseases in sugar beet. These microorganisms have the capability of root colonization. Spores of fungi like *Aureobasidium pullulans*, *Sporobolomyces papraroseus*, *Torulopsis candidus* or *Cladisporium cladosporioides* have been mixed with spores of *Phoma betae* and were sprayed on the plant for curtailing the development of the lesions in plants (Agnihotri 1990).

29.3 Benefits of Integrated Disease Management Approaches

IDM strategy is an amalgamation of preventive and manageable methods which shows promising results in controlling the pathogen from causing severe and strong impact on the sugar beet crop with a lowest human hazardous risk. The benefits of IDM are as follows:

1. Encourages healthy sugar beet crop
2. Encourages disease management through bio-based alternatives
3. Lowers risk related to environment due to disease management
4. Lowers the need of insecticides and pesticides usage and problems associated with pesticide residues.
5. Lowers soil and water pollution through use of environment-friendly products.

29.4 Future Prospects

The changing climate has caused the occurrence of many new sugar beet diseases, pathogens, and insect-pests. This has shown the importance of disease surveillance and forecasting for further managing new diseases in sugar beet. Though researches have been focused on developing resistant varieties particularly for soil-borne diseases that affect the beet root yield (the economical part), there is a need to strengthen the identification of such cultivars and their resistant sources through the amalgamation of conventional, modern, and advanced biotechnological tools. Microorganisms from the rhizospheric zone and endophytes also play important role in disease management and so there is a requirement of intensive study on root colonization of beneficial microbes in perspective of efficient bio-inoculants. The development of novel formulation is the urge of the current time for coping up with diseases. Furthermore, investigation on antagonists and bio-fertilizer application as bio-inoculant can be a further topic of research as these bio-inoculants will enhance sugar beet production and productivity.

29.5 Conclusion

Diseased sugar beet crops are of less economical value as the quality of sucrose gets deteriorated and this is one of the problems of growers which is concerning them to a great extent. Interaction between host, pathogen, and environment is necessary for the development of any disease. In order to protect plants from any disease, there is a need to manage all the three factors. The management strategy should involve the combination of all those methods where the host, pathogen, and environment get affected so as to protect the plant from any disease. Proper disease surveillance, disease forecasting, and its identification are some of the primary management strategy steps. Integrated management strategies for diseases have shown to be of much importance and efficient in obtaining healthy sugar beet crops. Integrated disease management involves the amalgamation of cultural, resistance, chemical, and biological control measures. By adapting to these strategies, growers could cope up with the significant losses they are facing due to disease infection in a sugar beet crop.

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