**Disease Management in Seed Production Fields**

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**Introduction**

Seed is the basic unit of multiplication of any crop. The Oxford Dictionary defines seed as “the unit of reproduction of a flowering plant, capable of developing into another such plant”. Technically, it refers to the fertilized, matured ovule that contains an embryonic plant, stored material and a protective coat or coats. Thus, it is unit of reproduction of both flowering and non-flowering plants. However, from the view point of farmers and agricultural scientists, seed is any part of a plant that is capable of regenerating into a new plant, it is a propagating unit and may be seed, cutting, tuber or part of tuber, corm, bulb, etc. There is a chain of physiological processes involved in this reproduction by plant, all of which are influenced by different genetic as well as environmental factors. There is s thermal memory of the plant that enables plants to acclimatize to their surroundings (Fernández et al., 2019).

The production of seed of any plant is influenced by the environmental conditions during the growth period. The crops in turn adapt to the changing environment by changes in their morphological and physiological processes (Fatima et al., 2020). As with any part of the plant, seed is also affected by the micro- and macro-environment that may affect it positively or negatively. Inderjit and Weston (2003) reviewed the different classes of primary and secondary root exudates produced by the different species and cultivars of the plants at different stages of life and under different environmental conditions. The interactions between environmental and genetic factors in the regulation of seed longevity has been reviewed by Zhou *et al.,* (2020). The positive impacts of environment are translated in the form of increased growth, production, and/or quality of produce. The negative influences may lead to reduction in yields, lowering the quality and quantity of produce and inoculum build up for the next years ‘growth. Among these negative influences, primary are the abiotic and biotic stresses. The abiotic stress may be caused by high or low temperature, high or low moisture, excess or deficiency or nutrients or other environmental factors. Among the biotic stresses are the insect, weed and disease problems which may prove to be a major bottleneck in realising the full genetic potential of the crop.

Some of the important diseases of seed crops are *Alternaria, Botrytis* of brassica species, onion, canola (Steentjes et al., 2021, Mahapatra et al., 2022); *Fusarium* wilt in spinach seed crops; *Stemphylium* blight of onion, garlic; downy mildew and white rust in vegetable crops (Hassan et al., 2020); viral diseases in legume and cereal crops (Jones, 2021, Kreuze et al., 2020); rusts in perennial seed crops and cereals; anthracnose stalk rot, charcoal rot, crazy top downy mildew ear and kernel rot of maize (ur Rehman *et al.,* 2021).

**Importance of disease management in seed production fields:**

Diseases affect the crop at all the stages of crop growth, after harvest and even in storage. However, disease management in seed production fields gains added importance because of a number of factors (Gaur et al., 2020). Some diseases become symptomatic when the crop enters the reproductive stage or at later stages of growth, e.g. *Stemphylium botryosum* on spinach (du Toit and Derie, 2001) or viruses infecting winter oilseed rape (Walsh et al., 1985). Such diseases are more important to farmers dealing with seed production than to vegetable growers. The long duration of seed crop gives ample opportunity to the pathogen to build up its population and increase the susceptibility of the crop. Pathogens also remain viable for a longer time in seeds than in vegetable parts. The seed in turn is more likely to survive for a longer time as compared to vegetative parts which are consumed quickly. The distribution of seeds in the national and international market leads to wider distribution of the seed and the accompanying pathogen. As a result, there is extremely low tolerance for pathogens in seed crops in the national and international markets. All the factors highlight the importance of disease management in the seed production fields.

**Disease Management Strategies**

The first and foremost step in any disease management strategy is correct diagnosis of the problem. Diseases may be caused by fungi, bacteria, viruses, nematodes or protists and each of them requires different management techniques. Some of the strategies are common for all types of pathogens like cultural practices, rouging of infected plants, sanitation, plant and soil health. However, most of chemicals used for fungi will not manage bacterial diseases and even all fungal diseases. Even the degree of control varies with the product and its concentration, environmental conditions and type of host plant. In general, disease management may be preventive, methods adopted to avoid or reduce the incidence of disease or they may be curative or therapeutic measures to cure the already infected plants. The preventive disease management methods include *avoidance*: preventing disease by selecting time or place or environment not favourable for disease development; *exclusion:* preventing the introduction of disease in disease free area; *eradication*: preventing infection by eliminating, destroying or inactivating the inoculum; *Protection*: preventing infection by formation of a protective zone between the host and the pathogen and *resistance:* by the use of cultivars or lines resistant or tolerant to infection by specific pathogens. The therapeutic or curative measures are utilized when a crop is already infected and we need to save the rest of the crop from destruction or keeping the disease below the threshold level. The focus of a plant pathologist is and should always be to focus to preventive rather than curative disease management strategies.

**Disease Management at Different Crop Stages**

Plants are affected at different stages of crop growth and are managed accordingly. However, for the ease of convenience, disease management can be divided according to the different stages of growth crop.

*Before planting the seed*: Before going for plantation of seed or establishment of new crop, it is advisable to know about the history of diseases in that area. Particularly, one should know about the soil borne diseases prevalent in the area as soil borne pathogens usually have long periods of survival in the field. One should also be aware of the environmental characteristics, structure and nature of soil as well as source and availability of water. The site should be selected keeping in view the drainage and sunlight exposure. It should then be prepared by removing debris, weeds, previous crop refuse and infected plant material. Unwanted plant material can be destroyed by burning or burying deep to prevent the survival and dispersal of the pathogen. Deep ploughing can also be done to achieve the same objective. Wherever possible, fields can be flooded to reduce weed population, disease inoculum and destruction of insects and insect eggs. One should practice crop rotation and prevent growing the crops belonging to same families for more than two years to break the pathogen cycle.

Seed and seedling diseases are more severe in poorly drained soils. Hence, particular attention should be paid to drainage and enhancing the structure and texture of soils. Fertilizer application should be devised on the basis of initial nutrient condition with proper amount and dose. Such type of fertilizers should be applied that do not promote disease or create conditions favourable for the pathogen. Use of organic and green manuring should be promoted as they result in healthy soils which in turn help plant growth that can resist diseases.

Healthy seed should be selected for sowing or planting. Seeds may be treated with bio-formulations, chemicals or other seed treatments. Such type of seed treatments provides extra layer of protection in soil during germination and early growth of the plants. *Enterobacter cloacae* was found effective in suppressing the damping off caused by *Pythium ultimum* and the inactivation of stimulation of the latter by seed exudates (Kageyama and Nelson, 2003). Similarly, application of *Trichoderma lignorum* reduced the infection of *Rhizoctonia solani* and increased the germination percentage in beans (Aziz et al., 1997). Always use certified disease-free seeds or planting material of high quality. Resistant or tolerant varieties, if available, should be preferred to reduce the impact of diseases and cost of cultivation.

If new seed or planting material has to be introduced, it should be first subject to quarantine or grow out test to ensure that it is disease free before planting in the main field.

*Management During Crop Establishment:* During crop establishment, particular care should be taken to maintain disease free crop. The production areas should be kept clean by removing crop debris, crop refuse, volunteer crops, weeds and other flora that can be a source of disease inoculum. The various equipment used for cultural operations should be kept clean to prevent dispersal of pathogen inoculum. Agricultural tools like shears, clippers, pruning scissors should also be kept clean or sterilized periodically. Sowing dates can be altered to help plants escape disease. The spacing between crops can also be adjusted to prevent favourable micro-environmental factors for pathogens. Scouting for diseases and rouging of infected plants plays an important role in maintenance of disease-free plots. Intercropping can be practiced for reduction of diseases in field. Care should be maintained during irrigation to prevent excessive watering that can help built up pathogen inoculum. Alternate dying and wetting of soils should be done to encourage beneficial micro-organisms to grow and destroy sclerotia or pathogen propagules. Wherever possible, drip irrigation can be done to prevent pathogen dispersal. Trap crops can also be grown to activate the pathogen and then starve it to death.

*Management During Flowering and Seed Development:* For seed production crops, this is thr most important time from disease management point of view. It is particularly important for the diseases that attack at the late stages of development and for seed borne diseases as they gain entry into the seed at this stage. Any disease appearance needs to be managed properly by timely application of chemicals or cultural practices need to be modified for the disadvantage of the pathogen. Fungicides can be applied wherever necessary and repeat applications may be needed under certain conditions. Field sanitation and rouging of infected plants continue to play an important role at this stage.

*Management During Seed Maturation:* During seed maturation and even after harvest, rainfall and humidity play a pivotal role and affect disease prevalence, incidence and intensity of diseases. Some diseases are more severe on the seed stalks or seed-bearing plant parts and warrant additional disease management. At this stage of crop, care should be taken to protect the crop from seed borne pathogens, particularly virus diseases. Any infected plant material should promptly be removed. Micro-environment of the crop should be modified to make it unfavourable for disease development. Care should be taken to provide adequate irrigation facilities without resorting to excessive watering so that the crop is not predisposed to infection.

*Management During harvesting and Threshing:* Harvesting and threshing of seed crops should be done in such a way that losses due to shattering are avoided and minimum damage is caused to the seed. The harvesting and threshing equipment and machinery should be kept neat and clean and if possible, sterilization of all the equipment should be done. Harvesting should be done at appropriate time and seeds should have optimum level of moisture for harvesting and storage.

*Management During Storage:* Before keeping the seed in storage, it should be thoroughly cleaned. Any broken, light weight seeds, chaff and foreign material should be removed. Only plump and healthy seeds should be kept for storage. All the seed should be dried to safe moisture level for storage. The seed can be treated with safe, eco-friendly and efficient seed protectants. The storage bins and rooms should be properly aerated with low temperatures to prolong the life of seeds. The rooms should be properly sealed to prevent the entry of insects, mites, rodents and birds.

**Conclusion:**

Disease management strategies vary from crop to crop and place to place. In most of the cases, disease management can be tailored to fit specific crops under specific conditions and keeping in mind the particular soil, water and climatic characteristics of the locality. For example the guidelines for quality seed production of summer squash have been given by Singh and Saxena (2020). Similarly, the guidelines for production of different crops are usually given in the Package of Practices of different crops by the concerned Universities. On a whole using the right type of seed or planting material, regular scouting and monitoring, adopting clean cultivation practices and use of integrated disease management schedule play a pivotal role in disease management of seed production fields. An integrated approach of combining all the management practices, most importantly bio-control agents with fungicides is of utmost importance in the management of plant diseases (Ons et al., 2020)

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