Pathological Status of Plant Germplasm and Sustainable Crop Production and Conservation

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Abstract

The rapid increase in world population requires a proportionate increase in food production for sustenance. The pathological status of cultivation material plays invaluable roles in plant genetic resource (PGR) management and sustainable crop production. Seed-borne pathogens pose a potential threat to global agriculture and plant conservation as evident in the amount of damage and wastage due to infected planting materials. PGR conservation is the management practice involving processes that actively retain the diversity within a gene pool with a view to actual or potential utilisation. In order to meet the food needs of our growing population, there is need to evolve efficient conservation strategies supported by sustainable crop production. High-quality seeds with good physical, physiological, health and genetic qualities are required to have greater prospects of producing a good crop stand and yield even under adverse environmental conditions. The process of avoiding seed contamination by pests and diseases begins with proper seed production and sterile storage practices. More so, seed-borne diseases can be controlled or suppressed through seed treatment during seed processing or prior to planting. Seed storage has proven to be a useful tool in contemporary plant conservation and crop production. Seeds to be held in seed banks should be properly handled according to standard protocols during harvesting and post-harvest to minimise infection. A good understanding of seed physiology, morphology, maturity and chemical composition, as well as appropriate storage condition, is required for efficient storage of seed for conservation and future use in crop production.

Keywords

Seed health, Plant pathology, Conservation, Crop production, Germplasm

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1. Introduction

The rapid increase in world population requires a proportionate increase in food production for sustenance [1]. Plant genetic resources (PGR) constitute the foundation upon which agriculture and world food security are based. PGR is the raw materials for breeding new plant varieties and a reservoir of genetic diversity. The importance of these invaluable resources is innumerable, hence, there is need to conserve them. According to Ogwu et al. [2], PGR conservation is the management of varietal diversity in plant occasioned by the interaction between genes and the environment for actual or potential and present or future use, which may be done in-situ or ex-situ. Crop production is the art, science and business of crop production and management, which includes many subfields with the aim of sustainable food production [3].

This timeless profession is practised globally. With each civilisation era, the practice has evolved and is currently faced with associated challenges. USDA [4] reported a decrease in the production of major economic crops. Such losses may result from diseases. Germplasm conservation is complemented by utilisation, which is made possible through crop production. There is need not only to conserve germplasm but also to improve production, utilisation and trade [5]. Seed pathology has a major role to play in PGR management and sustainable crop production as it determines the availability and suitability of seeds to be produced as well as their potential yield. Seed pathology is a branch of plant pathology and seed technology, which is the scientific study of diseases of seeds caused by pathogens and environmental conditions [6]. Pathogens are organisms that cause diseases and they can be fungi, nematodes, bacteria, protozoa, etc. [7]. Seed-borne pathogens pose a potential threat to global agriculture and plant conservation as evident in the amount of damage and wastage because of these diseases. This has rendered many seeds worthless and difficult to conserve resulting in the loss of genetic integrity. Majority of crop plants are propagated by seeds and depends on the viability of these seeds to reproduce. Therefore, if there is a problem with the seeds because of infection or disease, then, there might be a problem in the conservation of the hereditary materials held within these seeds. This, in turn, will influence the output from such seeds if they cultivated. Hence, great effort is required to ensure healthy PGR are conserved to support crop production.

The objective of this review paper is to highlight the importance of the pathological status of PGR held in storage with a view to cultivating them in the nearest future. These starting materials are the key to a successful crop production hence in this review, we consider the meaning of PGR and they can be conserved. Subsequent sections will also address seed biology and their health status as well as the roles of seed pathology in crop production and PGR conservation.

2. Plant genetic resources and their conservation

It has become increasingly clear during the last few decades that meeting the food needs of the world's growing population largely depends on the conservation and sustainable utilisation of the world's remaining PGR. PGR conservation is the management practice involving processes that actively retain the Intra and inter diversity inherent in a gene pool with a view of actual or potential utilisation [1]. Many species and varieties are becoming extinct and many others are threatened and endangered. To reverse these unabated gene erosions, conservation of genetic resources is a fundamental concern in conservation and other subfields of biology, as genetic variation is the raw material for evolutionary change within populations. The aim of conservation is to collect and conserve adaptive gene complexes. It has been shown that diseases can destroy crop varieties with a narrow genetic base.

The conservation of plant diversity is of critical importance because of the direct benefits to humanity that can arise from its exploitation in improved agricultural and horticultural crops, because of the potential for development of new medicinal and other products and the pivotal roles played by plants in the functioning of all natural ecosystems [8]. The diversity of plants is needed to keep the various natural ecosystems functions, services and processes stable [9]. In the same vein, Hammer and Teklu [8] opined that no organism exists alone but all depend on a magnitude of interactions that relate them together such as pollination and depend on a multitude of interactions that relate them together. Seeds are a convenient means of long-term storage of genetic diversity. Most spermatophytes are cultivated by seeds. These seeds need to be viable for germination to take place. Plants that are only propagated by seeds depend on the viability of these seeds to reproduce, and if there is a problem with the seed because of infection or disease, it might, in turn, affect the conservation of the hereditary materials and productivity, if they cultivated. Therefore, great effort is required to ensure healthy seeds are conserved and made available for cultivation.

To conserve means to keep in safety and protect from harm, decay, loss or destruction. It also means to use cautiously and frugally. There is a pressing need is for the conservation of crop genetic resources, but it is largely impractical to conserve the very large number of crop species and their wild relatives in their natural habitats. The major challenges of PGR conservation include population growth and urbanisation, pollution, habitat loss and modification, climate change, patent right for the protection of plant varieties, replacement of traditional varieties with modern ones, genetic vulnerability and diseases [2].

3. Seed biology and health status

Any plant part used for the multiplication of a crop is often referred to as seed [10]. Biologically, a seed is a fertilised, ripened ovule of a plant and consists of the embryo, nutritive tissue and seed coat, which under appropriate growth conditions will become the new plant. Thus, it is also regarded as the propagating organ particularly to spermatophytes, that is, gymnosperms and angiosperms. Seed health refers to the presence or absence of disease-causing organisms such as fungi, nematodes, bacteria, viruses and insects, and to the status of seeds in a seed lot [11]. Seed status is affected by the presence of non-disease-causing contaminants in a particular seed lot, which include contaminants like weed seeds that compete with the target seed for nutrients and other seeds, plant parts other than the target seeds, soil particles and insect eggs that can overwinter can degrade the quality of the seed lot [12]. A seed with dead embryo cannot germinate. Hence, harvested seeds must be properly stored for the embryo to remain viable [13].

Seed is the basic unit of crop production. When seeds are used for sowing, seed-borne pathogens may cause disease or death of plants resulting in loss of crops and food [14]. When these seeds are directly used as food or feed, seed-borne organisms may cause chemical changes, important deterioration in seed content, or mycotoxin release, with potentially harmful effect on humans and livestock, resulting in food waste or famine [15]. According to FAO [16] high quality seed with good physical, physiological, health and genetic qualities of seeds are required for farmers to have greater prospects of producing a good crop stand and yield even under adverse conditions although other factors such as rainfall, agronomic practices, soil fertility, and pest control are also crucial. Therefore ensuring seed health is important because the diseases initially present in the seed may give rise to progressive disease development in the field and reduce the commercial value of the crop and imported seed lots may introduce diseases or pest into new regions. Vizcayno et al. [17] opined that the main ways of avoiding seed contamination are to adopt proper seed production practices during seed production process and that seed-borne diseases can be controlled or suppressed by seed treatment during seed processing or prior to planting. Bonner [18] defined seed storage as mature seeds held for a short period until weather or other factors permit sowing or planting for the very short period, several years or long periods depending on seed physiology, morphology, maturity and chemical composition. FAO [16] recommended that successful seed storage should begin with proper seed handling during harvesting and post-harvest, which will minimize insect infestation, eliminate insect-infested seed before storage, dry the seed sufficiently to reduce the respiration rate of the seed, treat the seed with a suitable traditional or chemical insecticide and select a storage method and storage environment appropriate for the seed type and size as well as seed storage duration.

On a broad basis, seed storage may be divided into three categories based on seed tolerance to drying and low temperature into orthodox, recalcitrant and intermittent seeds. Orthodox seeds can be dried to very low moisture levels without damage and are largely applicable to seeds of temperate crops. Recalcitrant seeds cannot tolerate low temperatures hence should not be dried below their critical moisture levels. They are mostly succulents and cut across tropical and temperate crops. The critical levels of the moisture content of intermediate seeds below which more rapid loss in viability occurs during hermetic storage and/or viability are lost immediately after desiccation, varies considerably with species, the degree of maturity and the method of seed extraction or handling [19]. Intermediate seeds can be dried to moisture levels almost low enough to meet orthodox conditions (12 to 15%) but are sensitive to the low temperatures typically employed for storage of orthodox seeds and viability is retained usually only for a few years [18].

Various techniques have been developed for preserving seed in order to retain their viability for longer periods by regulating temperature (around -20^{o}C or in liquid nitrogen around -196^{o}C) and humidity (using silica gel in the holding containers), which are very critical factors [20]. Seed storage has proven to be a useful tool in contemporary plant conservation as well as crop production. Proper storage techniques make it possible to sow and plant when convenient instead of having to schedule around seed availability. Stored seeds are an important backup for plants that are threatened with extinction in the wild. For this purpose, long-term storage over many years is the goal.

Long-term storage is also appropriate for germplasm conservation in seed storage facilities. A valuable feature of seeds for this purpose is that each seed is a genetic individual, but requires far less space and upkeep than an individual in the greenhouse or in tissue culture. Unlike money, seeds in a storage facility are a diminishing asset, so storage conditions that best minimise deterioration are critical, and there must be plans for periodically refreshing the collection. Seeds in the seed banks are protected from field pests and pathogens while in storage but are at risk of infection from innate seed borne pests and pathogens, which may persist [20].

4. Roles of seed pathology in crop production and pgr conservation

Plant pathology is the study of plant disease with the objective of studying the living entities, non-living and environmental conditions that cause disorders in plants, the interacting mechanisms between host plant in relation to the overall environment and the method of preventing or managing the diseases [21]. A disease is defined as any physiological disorder or structural abnormality that is deleterious to the plant, its part or product, which reduces the economic value of the plant [22].

Seed Pathology is an integral part of seed technology and plant pathology, which deals with seed diseases, seed borne plant diseases, their detection and management. It is the aspect of general plant pathology that includes the relationship of plant pathogens to all types of propagative materials including commercial and weed seeds, and other plant-propagating materials such as cuttings, scions, tubers, and meristem propagules. All the principles that apply to the study of diseased seedlings and plants can be applied to seed pathology [7]. Seed disease is the result of an interaction over time, between a susceptible host, a pathogen, the environment, and a transmitting agent, resulting in signs or symptoms of such effects [23].

Any infectious agent associated with seeds, that has the potential of causing a disease of a seedling or plant should be termed a seed-borne pathogen, which includes all plant pathogenic bacteria, fungi, nematodes and other microorganisms and virus of all of which can be carried in, on or with seeds [7]. Nameth [6] suggested that seed pathology includes studies on the mechanism of infection, seed transmission, the role of seed-borne inocula in disease development, techniques for the detection of seed-borne pathogens and nonpathogens, seed certification standards, deterioration due to storage fungi, mycotoxins and mycotoxicoses and control of seed-borne inocula while listing seed treatment and pathogen detection and identification as requiring research priorities. Seed treatment refers to the application of certain agents physical, chemical or biological to the seed prior to sowing in order to suppress, control or repels pathogens, insects and other pests that attack seeds, seedlings or plants and it ranges from a basic dressing to coating and pelleting [24]. The procedure offers an increasingly precise mode of applying products in the field and provides a high level of protection against insects and disease while reducing potential exposure of humans and the environment to crop protection products [25]. Seed treatment may be carried out through a variety of chemical, biological, physical, and mechanical approaches have been used to eliminate pathogens from the internal and external portion of seeds, and to help protect seeds from soil-borne pathogens [6]. Recently, hot water treatment of seed, acid treatments or other methods, continue to be a standard method of pathogen elimination in seed because they are more eco-friendly and effective compared to chemical treatments (particularly hot water) and effective; however, they can cause the loss of seed viability. Identifying, testing, and developing biological seed treatments appear to be an area where much research effort is occurring and will continue in the future. The use of naturally occurring beneficial fungi and bacteria to control other fungi and bacteria is not a new idea; however, due to the renewed interest in the environment and the establishment of worker protection standards, research in this area is going through a renaissance. There is a variety of biological control agents used to treat seeds that are currently in various stages of development. Serological-based seed assays, such as the enzyme-linked immunosorbent assay, continue to be used with some success for bacteria, fungi and virus. However, they lack the specificity and sensitivity needed to detect many seed-borne viruses. Treatment of vegetable seeds has been shown to prevent plant disease epidemics caused by seed-borne fungal pathogens [26].

Some of the effects of seed-borne pathogens include; reduction of crop yield, loss of germination and vigour, discolouration and shrivelling biochemical changes [7]. FAO [27] proposed a set of standards for conservation of plant genetic resources with the aim of reducing seed borne pathogens in gene banks and includes:

1) Standards for the drying and storage of orthodox seeds

2) The standard for seed viability monitoring

3) Standards for evaluation

4) Standards for hydrated storage of recalcitrant seeds

5) Standards for in vitro culture and slow growth storage

6) Standards for cryopreservation

5. Recommendations and conclusion

Seeds must be properly tested before it is accepted in seed/gene banks or used for the purpose of crop production. A seed that has not been properly tested may have been infected and when the seed is brought into the gene bank or cultivated, the disease it carries may spread across and infect healthy seeds or affect crop output in the field. Pathologists should assess seeds before they are cultivated. More so, seed conservation centres should employ seed pathologists who should check the seeds' health at regular intervals in order to detect the presence of disease or pathogens at the earliest before spreading to other seeds. This will help reduce the amount of seed lost to pathogens. Also, proper hygiene should be practised in every conservation area. So, conservation sites should be properly cleaned at all times. Every germplasm collection should always be maintained according to the gene bank standard for seed storage given by FAO of United Nations, which will help reduce the level of seed infestation. The importance of PGR cannot be overemphasised and they need to be conserved for continuous availability of food and raw materials. Despite the great harm seed pathogens pose to crop production and plant conservation, it can still be harnessed by taking into consideration the causes of seed infestation, mode of infestation and ways to eradicate pathogens in the seed. If the standards given by FOA are strictly adhered to, in the long run, the loss of yield and genetic resources caused by seed pathogens may be curbed.

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